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April 1993

Eastside Forest Ecosystem Health Assessment

Volume I
Executive Summary

This report is not intended to provide precise details on all aspects of ecosystem management. The report responds to seven questions concerning the sustainability of ecosystems in eastern Oregon and Washington, and the effects of historical management practices on sustainability of those ecosystems. This report is not a "decision document" as defined by the National Environmental Policy Act (NEPA). It does not allocate resources on public lands nor does it make recommendations to that effect. Implementation of ecosystem management on Forest Service administered lands is the responsibility of the National Forest System and Forest Service Research. Implementation is done through forest and project plans that are subject to the NEPA process of disclosing the effects of proposed actions and affording the opportunity for public comment. The information contained in this report is general in nature, rather than site specific. In making land management decisions and establishing standards and guidelines National Forest System personnel may consider this information as well as a wide variety of other information received in the course of complying with the National Environmental Policy Act, and other laws. The opinions expressed by the authors of the papers in this volume do not necessarily represent the policy or position of the Department or the Forest Service.

Eastside Forest Ecosystem Health Assessment

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ABSTRACT

This report responds to the request by Speaker Foley and Senator Hatfield for a scientific evaluation of the effects of Forest Service management practices on the sustainability of eastern Oregon and Washington ecosystems. The report recommends analysis methods and management practices that can be used to build an experimental approach to the restoration of stressed ecosystems.

A total of 113 scientists from universities, Federal and State agencies, and private companies, contributed to this report. Their research provides the basis for a sustainable ecosystem management framework to evaluate the effects of management practices on ecosystem sustainability, and recommends strategies for restoring or rehabilitating stressed ecosystems.

Current and historical landscape attributes were characterized and compared for a 1.1 million-acre sample of river basins in eastern Oregon and Washington (Figure 1) in this assessment. Change in fish habitat conditions of four river basins was also studied. Terrestrial assessment data were compiled and interpreted with the assistance of more than 115 National Forest System employees. Spatial analyses were performed to determine differences in historical and existing vegetation patterns. Previous management practices were evaluated to determine their effects on current ecosystem conditions.

The following changes in eastside ecosystem conditions have occurred during the last 40 to 55 years:

- ❑ Forest fragmentation and landscape diversity increased in intensively managed watersheds, but declined in wilderness or roadless areas.

- ❑ The acreage of early-seral, late-seral, and climax stands has decreased, while mid-seral stand acreage has increased. Additionally, the abundance of young and old forest structural stages has declined, and middle-aged structural stages have increased. Such changes have important consequences for species and landscape diversity.

- ❑ Significant differences in insect and disease hazard severity were not detected at the river basin level due to high within-basin variability; however, some watershed hazards were substantially changed. The largest increases and decreases in specific insect or disease hazards indicate that these disturbance processes have been greatly altered by management.

- ❑ Tree densities, fuel loads, fuel continuities, and fire hazards have increased in some watersheds, and decreased in others. The assessment analysis was not able to evaluate the contribution of green fuel ladders to fire hazards because appropriate fuel models were unavailable; however, these fuels may be one of the most important fire hazards on the eastside.

- ❑ Riparian vegetation and associated fish habitats have been adversely affected in many watersheds by grazing, roading, irrigation, and flood control practices.

- ❑ Fire disturbance regimes have been altered through fire suppression especially on sites adapted to frequent, low and moderate severity fires.

The new Forest Service ecosystem management philosophy requires an experimental approach to the creation and maintenance of sustainable ecosystems. Ecosystem management must be an experimental and adaptive process because of the uncertainties that exist concerning societal values and expectations, the processes that shape such values, and the capacities and responses of ecosystems. In the adaptive management approach, hypothesis testing, experimentation, monitoring of social and ecological attributes and their positive and negative feedbacks, and experiment refinement are used in designing management systems. Societal values and expectations, and the capacities of ecosystems to meet those expectations, can be expressed in alternative landscape designs through this process.

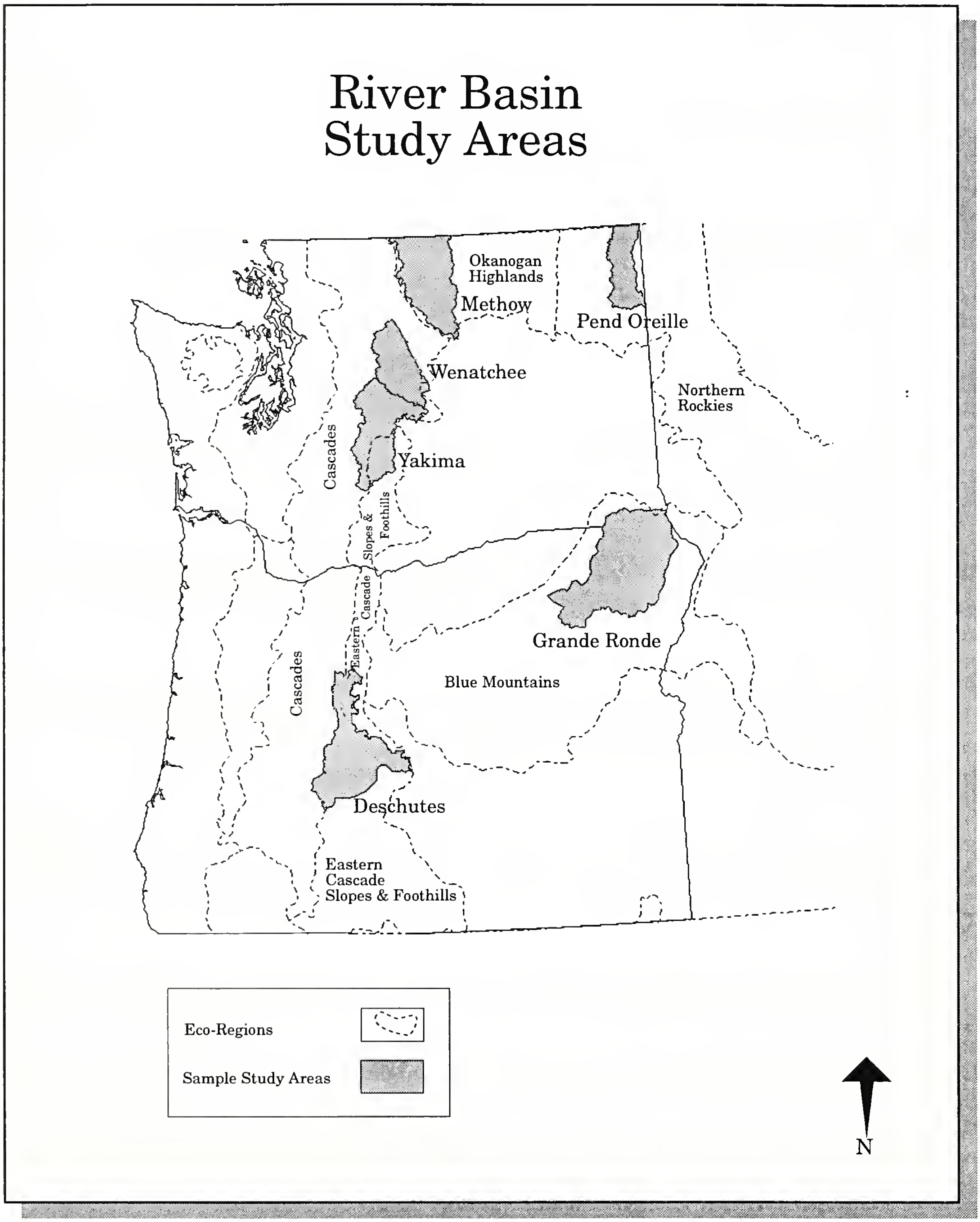

Figure 1. Forested ecoregions of eastern Oregon and Washington and the 6 sampled river basins of the Eastside Forest Ecosystem Health Assessment of 1993.

Few management practices are either universally beneficial or damaging to ecosystems or landscapes, but management practices can be damaging to ecosystems when they are done at the wrong time, place, or scale, or are applied for inappropriate objectives. The correct timing, location, and scale of management practices is determined by clearly articulated local and regional landscape management goals, quantifiable objectives, and interdisciplinary planning. Management practices are currently available to initiate management of landscapes and ecosystems. We provide an initial process for developing landscape prescriptions for ecosystem management, but recognize that much developmental testing is required to provide a solid base for making land management decisions.

Five alternative levels of investment in ecosystem management are presented, from a minimum investment that results in avoidance of catastrophic losses of forested landscapes, species, habitats, and long-term site productivity, to a maximum investment rate, where all eastside landscapes are restored to sustainable conditions, with sustainable resource flows. A socioeconomic analysis should be conducted for each alternative investment level so that people understand the costs, benefits, risks, efforts, and tradeoffs associated with each choice. Ecosystem management should be a very social process whereby the Forest Service enters into a continuing dialogue with people concerning the lands they manage on their behalf. New information should be jointly considered, analysis and planning efforts should be collaborative, and management decisions should fully consider societal values.

INTRODUCTION

Overview of Eastside Ecosystem Issues

Federal action to restore sustainability of forests in eastern Oregon and Washington was prompted by two cardinal issues. People served by the Forest Service have redefined their expectations for public lands. The importance of clean water and air, soil productivity, conservation of wildlife and plant species and their habitats, and wise use of renewable resources is increasingly stressed in public opinion. The second issue demanding attention is that of increasing hazards; that is, hazards of insect outbreaks, disease epidemics, and severe fire in eastern Oregon and Washington. Associated with these hazards is the potential loss of sensitive fish stocks, and bird and mammalian species from over-use of forest resources and loss of essential habitats (U.S. Department of Agriculture 1991).

This shift in public expectations caused the Forest Service to adopt a national strategy of ecosystem management to emphasize conservation of biodiversity, long-term productivity, and the capacity for sustained flows of renewable resources (Overbay 1992). Increasing hazards and declining diversity and productivity in eastern Oregon and Washington caused people to question the scientific basis of Forest Service management practices.

In public forums in eastern Oregon and Washington, people discussed strategies for restoring forested ecosystems, preventing catastrophic fires, minimizing insect and disease damage, increasing economic stability, and ensuring production of forest products (U.S. Department of Agriculture 1991). Participants suggested Forest Service management should emphasize maintaining biodiversity, including sensitive plant and animal species, fisheries, big game, and unique habitats (riparian and old growth). Participants further suggested that, where possible, management should mimic natural processes, including fire, and it should characterize historical landscapes and other unmanaged sites as management reference points.

Results presented in Volume III of this report (Assessment) indicate that *not all eastside landscapes are being destroyed by insects or diseases, nor are they all in immediate risk of catastrophic fire. Substantially elevated fire hazards and large scale insect outbreaks, however, are evident in some watersheds, and intensively managed forests are fragmented.* Landscape vegetation patterns have changed from historical conditions in most

managed landscapes, and grazing and timber harvest activities have seriously impacted some riparian zones, streams, and native fish stocks. Based on this evidence, the request for scientific information on the condition of eastside forest ecosystems and their need for restoration was timely and warranted.

THE ASSIGNMENT

Speaker Foley and Senator Hatfield, responding to concerns of their constituents, requested that the Secretary of Agriculture convene an interagency science panel (appendix A) to evaluate current ecosystem sustainability and appropriateness of management practices, and to make recommendations for restoring stressed ecosystems. The science panel was also asked to evaluate the adequacy of scientific information for managing eastside forest ecosystems sustainably. Former Secretary of Agriculture Madigan responded with a letter directing the Forest Service to create an interagency science panel to address the major points in the Hatfield/Foley letter. Those points are presented in the form of questions below:

Question 1 What process should be used to generate and evaluate alternative sustainable ecosystem management scenarios?

Question 2 Is the available scientific information adequate to prescribe for sustainable ecosystems?

Question 3 Are eastside ecosystems in Oregon and Washington stressed and in need of restoration?

Question 4 What are the effects of management practices on ecosystem sustainability? What changes are needed in current management practices? What are the knowledge gaps that prevent adequate evaluation of current management practices?

Question 5 What are alternative ecosystem management scenarios? What process should be used to evaluate alternative levels of investment in ecosystem management?

In discussions with Speaker Foley's and Senator Hatfield's staff it was jointly agreed that the science panel should address monitoring for ecosystem management, and identify information gaps and research needs stemming from the five questions above.

Question 6 What monitoring strategy is appropriate for maintaining sustainable ecosystems?

Question 7 What are the information gaps and research needs in prescribing and managing for sustainable ecosystems?

Findings of this panel were to be provided in a manner readily understood and used by National Forest System personnel.

THE APPROACH

A total of 113 scientists from various agencies and universities contributed to the five volumes of this report. The following is a summary of the contents of those volumes:

Executive Summary: Volume I

This summary volume provides responses to questions raised in the letter from Foley and Hatfield based on the findings and recommendations provided in the other volumes. Information is also provided concerning monitoring strategies for sustainable ecosystems and information gaps and research needs for ecosystem management.

An Implementation Framework for Ecosystem Management: Volume II

This document describes the theoretical basis for experiments in ecosystem management and provides suggestions for putting this management philosophy into practice. This volume also provides a scientific basis for evaluating the effects of management practices on sustainability of forested ecosystems. It is divided into sections that describe the historical development of the ecosystem management concept; the ecological principles that support ecosystem management and their relation to sampling design and data analysis; case studies that demonstrate ecosystem management application on the ground; and strategies for implementing ecosystem management that address socioeconomic, planning, landscape ecology, and adaptive management considerations.

Assessment: Volume III

The dynamic nature of eastside ecosystems is described in terms of climate change, landscape succession, effects of disturbances, and effects of Native Americans and European settlers on landscape and stream characteristics. The effects of Forest Service management practices on previously altered ecosystems are evaluated and described in detail. The effects of selective harvesting, tractor logging, pest and fire suppression, livestock and wildlife grazing, roading, mining, custodial land management, and water withdrawal for irrigation are discussed. The major effects of fire and pest suppression and selective harvesting are described in terms of modified hazards, landscape patterns, and disturbance processes.

This volume applies the concepts and principles reviewed in Volume II in an assessment of a representative sample of terrestrial eastside landscapes. Current landscape structure and composition are contrasted with historical conditions. Changes in conditions as a result of management practices are analyzed and evaluated. A sample of eastside river basins are also evaluated to determine changes in fish habitats over the last 50 years. Current stream channel conditions are contrasted with historical conditions to determine the magnitude of change.

Restoration of Stressed Sites and Processes: Volume IV

Recommendations for restoring or rehabilitating important eastside ecosystem disturbance processes (fire, insect, and hydrology) and stressed ecosystems (riparian areas, rangelands, over- stocked forest stands) are provided. Avoidance of catastrophic loss of species and forested habitats is discussed, and recommendations are included for conserving soil and water productivity, unique habitats, and sensitive wildlife species.

A Broad Strategic Framework for Sustained-Ecosystem Management: Volume V

An ecosystems approach was used to develop a decision process and a management model on which to base sustainable-ecosystem management. The vision for this framework was not limited geographically or by existing laws and regulations. People are considered as important ecosystem parts, and societal processes as important ecosystem mechanisms. The concept of managing as an experiment is presented. Society would participate in the design of an array of scientifically based landscape treatments in which projected outcomes are compared to actual outcomes. Ultimately, more societal processes and more science--both natural and social--needs to be included in the management system itself.

The information contained in these five volumes provides the scientific basis for addressing the seven questions presented above. Additional information from ongoing research studies was also used in addressing these questions as instructed by the Secretary of Agriculture. The information and concepts provided in response to the questions represent a synthesis of these supporting documents. This Executive Summary was a joint effort between the assessment team leader, science team leaders, and other scientists of the original science panel (appendix A). Individuals given primary responsibility for developing each question were as follows:

Question 1	M. Jensen, P. Bourgeron, P. Hessburg, R. Everett, B. Bormann
Question 2	M. Jensen, P. Bourgeron, R. Everett, P. Hessburg
Question 3	P. Hessburg, R. Everett
Question 4	P. Hessburg, R. Everett, C. Oliver, A. Youngblood
Question 5	P. Hessburg, R. Haynes, R. Everett
Question 6	R. Everett, P. Hessburg, M. Jensen, J. Lehmkuhl, R. Wissmar
Question 7	R. Everett, P. Hessburg, W. Krueger, B. Bormann

The authors of this summary paper (appendix D) acknowledge that they report the collective work of a larger group of scientists. Those listed above are solely responsible for the content of the summary paper, as are the individual authors for their contributions to the other volumes of this report.

Sustainable Ecosystem Concepts

Eastside forest ecosystems are characterized by change. Disturbance events (e.g. fire, insect, disease, and floods) create and maintain a shifting mosaic of landscape patterns. These landscape patterns (e.g. spatial arrangements of plant communities) provide an array of resource values. Two working hypotheses of ecosystem management are (1) human values and expectations can be incorporated into ecosystem management by identifying landscape patterns that are representative of these values and (2) sustainable ecosystems can be achieved by integrating people's expectations with the ecological capacities of ecosystems. The social, biological and physical components of sustainable ecosystems are hierarchically interrelated and these relations provide the context for defining sustainability.

In this report, sustainability of ecological systems is defined by the historical range in variability of ecosystem patterns and processes at multiple hierarchical scales. The coarse-filter conservation strategy of Hunter (1991) suggests that the maintenance of historical landscape patterns and processes conserves the biological diversity that evolved under those conditions. Principles of landscape ecology and conservation biology are emphasized because they provide a foundation for experiments in ecosystem management (Lubchenko 1991, NRC 1990, SAF 1993, U.S. Department of Agriculture 1992a). These disciplines are rapidly evolving, consequently the principles outlined in this report must be refined as new information becomes available.

Ecosystem management must be implemented as an experiment because of our evolving theoretical base, uncertainties concerning society's expectations, and an incomplete knowledge of ecosystem structures and processes. The adaptive management process (Walters and Holling 1990) provides a basis for immediate implementation of ecosystem management. In this process goals and objectives are clearly stated, an initial hypothesis of ecosystem behavior is described, and monitoring is conducted to provide rapid feedback for redirection of management experiments.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Question 1: What process should be used to generate and evaluate alternative sustainable ecosystem management scenarios?

(References: Volumes II and V)

The philosophy of ecosystem management is to sustain the patterns and processes of ecosystems for the benefit of future generations, while providing goods and services for each generation. The challenge is to define characteristics of ecosystems and landscapes that promote long-term ecological sustainability, and to manage land and water ecosystems in ways that maintain that sustainability and conform with societal values and expectations.

The process referenced in question 1 is achieved by incorporating ecosystem management concepts into land-use planning. In this approach, common definitions of ecologically and socioeconomically sustainable ecosystems are incorporated into "desired future condition" statements and implemented through integrated land evaluation and land use planning. The planning process develops and evaluates alternatives for sustainable-ecosystem management.

Applied Conceptual Framework for Ecosystem Management

Land evaluation methods (Beek and Bennema 1974) provide a conceptual foundation for ecosystem management that has been adopted by the Food and Agriculture Organization, International Society for Soil Sciences, and others in agricultural, rangeland, and forestry land-use planning efforts. Zonneveld (1988) suggests that this process is appropriate to both local and regional planning efforts, and recommends that integrated land evaluation consider: sociological (human needs and wants), land and water ecology (ecological possibilities), technology (tools available to managers), and economic (available funds) factors. Simultaneous integration of all factors provides optimal land-use alternatives.

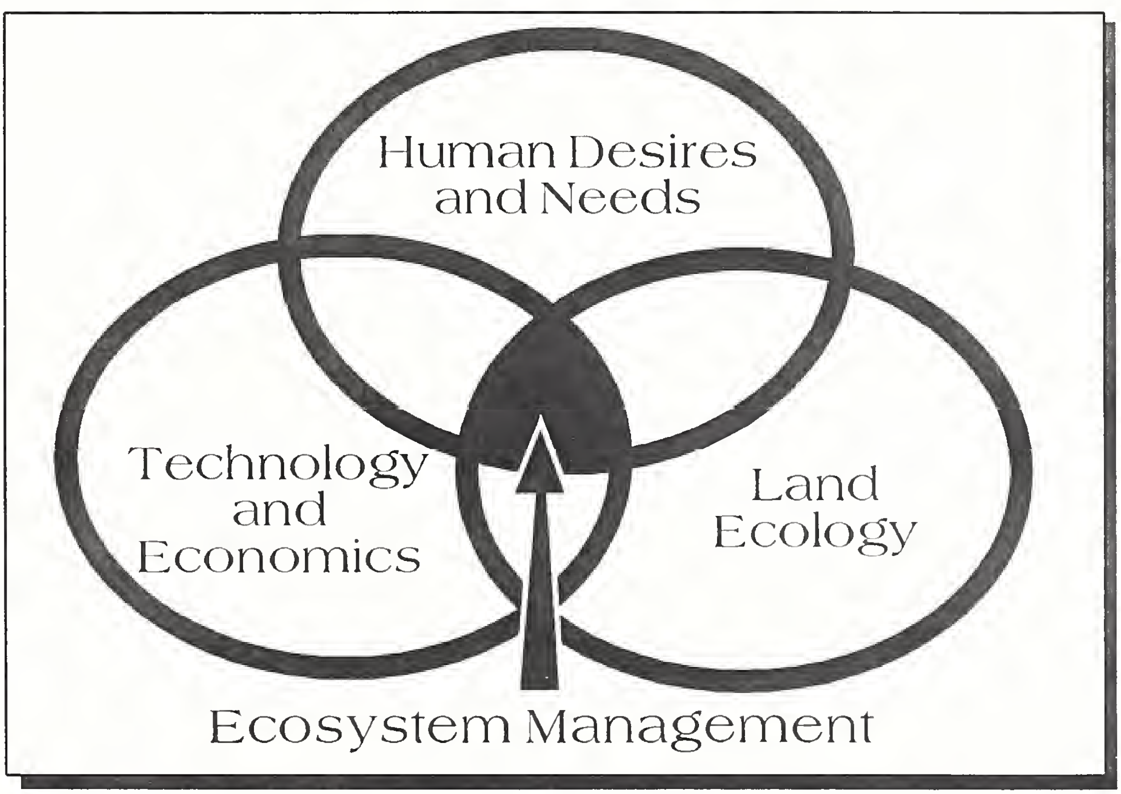

Figure 2. Framework for ecosystem management following principles of land evaluation (Zonneveld 1988).

We present a modification of Zonneveld's concepts in Figure 2, where *ecosystem management is displayed as the optimum integration of societal values and expectations, ecological potentials, and economic plus technological considerations.* The following is a general listing of steps that describe how the land evaluation process may be implemented to achieve ecosystem management:

- Determine the desires and requirements of the people who will be influenced by the planning outcome.

- Describe the ecological potentials of the analysis area for meeting stated societal needs. Such descriptions must include the following items: a description of the range of conditions required to maintain long-term ecosystem sustainability, a description of current conditions, and a description of desired landscape conditions that achieve societal needs.

- If desired landscape conditions fall outside the range of conditions that are required for long-term ecosystem sustainability, affected publics need to be informed of this fact. Public awareness of ecosystem potentials is critical to the development of achievable "desired future condition" strategies for land management. Public desires are further refined through this process, based on an understanding of sustainable ecosystem criteria.

- Once a socially acceptable, sustainable vision of landscape conditions is achieved, it is then contrasted against available technology to determine if it can be implemented. For example, in many instances the desired landscape condition may differ from existing conditions. In these situations, factors such as system design and equipment availability are considered to determine if it is technologically feasible to move the existing landscape to some desired set of conditions.

- Economic factors are also used to determine what parts of the stated human desires can be fulfilled. If resources (economic and technology) are not available to implement management of desired landscape conditions, affected publics should be notified and alternative strategies developed. *In most situations, short-term economic reasoning and large technological impacts contribute to situations that violate land ecological and human values (Zonneveld 1988).* Accordingly, they should be avoided in the development of strategies for ecosystem management.

Maintaining sustainable ecosystems (as a basic tenet of ecosystem management) requires constant interaction with people. Ecosystems are managed to ensure that the values and expectations of people are met now and in the future. An in-depth understanding of the ecological potentials of land and water systems and of ecosystem interactions is required if land management decisions are to provide sustainable ecosystems for future generations. The following discussion provides general recommendations concerning the social, ecological, economic, and technological components of land evaluation:

Social Elements of Ecosystem Management

Human values and expectations (as reflected in public environmental laws, RPA, forest plans, and project decision documents) shape the goals of ecosystem management. The greatest challenge to ecosystem management is to ensure that public expectations are compatible with ecological potential.

Perceptions and risk preferences strongly influence public expectations of forest management policies. *The uncertainties of ecosystem management (outputs, outcomes, expectations) require flexible policies to accommodate changing public perceptions of risk.* Collaboration (i.e., interdependent groups working together to affect resolution of an issue) should increasingly be used in resolving social conflicts that arise from ecosystem management.

Public participation is a major component of the forest planning process. New approaches to implementing forest plans, such as Integrated Resource Analysis (IRA), provide improved forums for exchanging information with people about ecological conditions and trends on public lands. The IRA process may also be used to minimize conflicts between different communities of interest through mutual development of ecologically sound descriptions of future landscape conditions.

Ecological Factors

Determining ecosystem interactions and potential is a major part of sustainable ecosystem management. The theory and principles developed in landscape ecology and conservation biology provide a solid foundation for experiments in ecosystem management. *These principles and theories have been embraced by a wide variety of professional societies and agencies in their attempts to develop strategies for maintaining healthy ecosystems to accommodate rapid human population growth and associated resource demand* (Lubchenko and others 1991, NRC 1990, SAF 1993, U.S. Department of Agriculture 1990).

Some of the major landscape ecology and conservation biology principles applicable to ecosystem management are summarized below:

- ❑ Hierarchy theory. The development and organization of landscape patterns such as vegetation communities is best understood in the context of spatial and temporal hierarchies. Disturbance events that maintain landscape patterns also depend on spatial and temporal scales. An understanding of the hierarchical nature of ecosystems is critical to the development of management strategies for ecosystem sustainability.

Developing these principles into management practices requires that land evaluations be made at multiple scales of ecological description and definition. The spatial and temporal variability of landscape vegetation succession should also be addressed in land evaluation.

- ❑ Natural Variability. All land and water ecosystems vary across time and space, even without human influence. Knowledge of this variability is extremely useful in determining whether the current condition of a landscape is sustainable, given historical patterns and processes.

Descriptions of historical landscape disturbance regimes such as fire magnitude and frequency, and the patterns of ecosystem components such as vegetation composition and structure, provide an initial template for describing ecosystem sustainability. Delineating similar biophysical environments (ecological units) is necessary to describe processes and patterns in land evaluation and analysis.

- ❑ Coarse-Filter Conservation Strategy. The conservation of genetic, species, and landscape diversity is the primary method for maintaining the resilience and productivity of ecological systems.

This approach assumes that if similar landscape patterns and processes are maintained to those that governed species evolution and survival, a full complement of species will persist, and biodiversity will be conserved. Application of this concept to management practice requires understanding the natural variability of landscape patterns and processes. Accordingly, landscape ecology principles provide the foundation for ecosystem management.

Economic and Technological Factors

Nonmarket ecosystem products and services (e.g., biodiversity, clean air) are not well considered in most traditional economic systems. Much effort is now being directed towards developing common units of measure that integrate market and nonmarket resources in describing "natural capital stock" (Pearce and Turner 1990). Advances in ecological economics will improve the integration of economic principles with land-use planning. Managing to achieve ecosystem management goals can be facilitated through regulations

or economic incentives. Regulations have traditionally been used to emphasize certain values in land management (e.g., water quality, tree stocking levels), but such regulations often stifle economic growth and may be inappropriate to some local conditions. *Thus, economic incentives may be required if some ecosystem values (e.g., biodiversity) are to be maximized on both public and private lands.* New technologies (e.g., geographic information systems, remote sensing, harvesting systems) will also need to be increasingly used in ecosystem management efforts.

Ecosystem Management and the Planning Process

The Forest Service's land management planning process is the mechanism for translating the policy and concepts of ecosystem management into action. Traditional planning emphasized individual resources and provided only limited consideration of spatial and temporal relations. Ecosystem management requires that the dynamic nature of landscape patterns and processes be considered in the planning process. *Integrated resource analysis provides excellent opportunities for integrating ecosystem management concepts into Forest Service decisions.* Existing monitoring and evaluation procedures should be modified to more explicitly address multi-scale ecological and social factors. Regional- and watershed-scale analyses will be required to address many eastside issues such as forest health or fire management.

Volume V presents a management model that emphasizes the need for integration of societal and biological objectives at national, regional, and local scales, and the linkage of information upward and downward among scales. In this approach, societal values and biophysical capacity are "laced together," which implies many interactions rather than a linear planning process (Figure 3). Accordingly, different processes must be used at different geographic scales to make decisions.

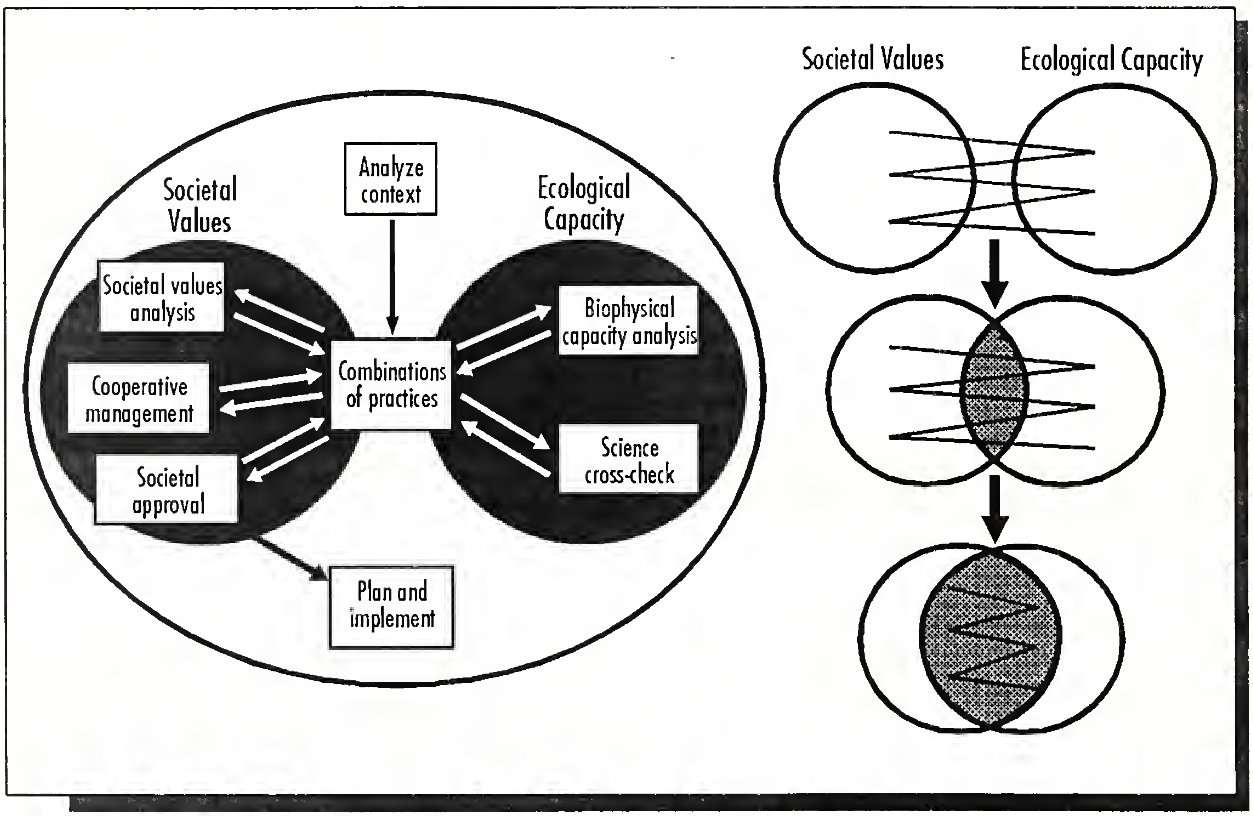

Figure 3. An iterative decision process for any geographic scale to "lace" together societal values and ecological capacity of the ecosystem.

Question 2: Is the available scientific information adequate to prescribe for sustainable ecosystems?

(References: Volumes I and II)

Introduction

If premanagement-era conditions are used as a reference point, sufficient information exists on the eastside to prescribe for improved sustainability of ecosystems that are currently outside historical ranges of variability for landscape pattern and hazard (Caraher and others 1992). This process facilitates prescriptions that reduce current ecosystem stress, but prescriptions for long-term ecosystem sustainability require a more in-depth analysis of social values and expectations, and the description of the desired sustainable ecosystem.

Several alternative ecological states (landscape conditions) that vary in their biodiversity, and their capacity for sustained flow of renewable resources, can be achieved through management. Desired conditions, however, are those that maintain ecological integrity (structures, processes, interactions, and species), retain a full complement of future options, and meet as many societal expectations as possible.

Principles of landscape ecology and conservation biology provide a theoretical basis for ecosystem sustainability diagnosis. Inventory, classification, and analytical tools are also available to conduct landscape-scale assessments of ecosystem sustainability (see Volumes II and III). The major limiting factors to ecosystem management prescriptions currently include: defining national, regional and local societal expectations; integrating those expectations with the potential composition, structure, and function of landscapes; lack of quantitative information on the current and historical conditions of landscapes; and lack of information on successional dynamics following disturbances.

Prescriptions for ecosystem sustainability can be made only where landscape- and ecosystem-scale information has been collected, analyzed, and interpreted, and integrated with societal expectations. Before sustainable ecosystem management can be prescribed, current social expectations and values must be described in terms of landscape structures, compositions, and patterns. These descriptions in turn can be evaluated for ecological sustainability. Such evaluations are made at multiple spatial scales to ensure that the relation between ecosystem patterns and processes is properly identified.

Adaptive Ecosystem Management to Deal With Uncertainties

Prescriptions for sustainable ecosystems will be made in an environment characterized by much ecological and socioeconomic uncertainty. *Managers must conduct their ecosystem management process as adaptive management experiments* where needed information is developed through management experiments, and useful information is applied to subsequent experiments. Adaptive management requires quantification of clearly articulated objectives, a stated understanding of system operation, rapid feedback and evaluation, and redirection of management. Flexibility in management is required to (1) adapt to new information, (2) adjust to unpredicted ecosystem developments and natural disturbances, and (3) facilitate changes in goals.

Management for Sustainable Ecosystems is Experimental

Ecosystem management can be conducted as an experiment and the process of experimentation should begin immediately. Knowledge of ecosystem processes will never be complete, but the risks of ecological loss associated with no explicit management strategy for dynamic ecological systems are greater than those incurred under a formal experimental process.

Eastside Oregon and Washington forest ecosystems have changed considerably in the past and will continue to change in the future. Current conditions of some landscapes fall outside the historical ranges of variability for insects and diseases, fire, grazing, and hydrologic disturbances. The sustainability of these landscapes can be restored through ecosystem management. Inaction may result in the occurrence of disturbances that create rapid, large-scale changes in landscapes that are inconsistent with societal expectations.

Societal Values and Expectations

More information is needed on societal values and expectations for eastside forests as people become increasingly aware of ecological potentials. Public forums on forest health in eastern Oregon and Washington indicated that local and regional communities want ecosystems restored, catastrophic fires prevented, insect and disease damage reduced, economic stability increased, and flows of forest products continued (U.S. Department of Agriculture 1991).

Participants at the forest health workshops agreed that ecosystem management was an appropriate approach, and that special attention should be given to maintaining biodiversity, including sensitive species, fisheries, big game, and fragile habitats (riparian and old growth). Participants suggested that management should mimic natural processes, including the reintroduction of fire, and the use of historical landscape and unmanaged site characteristics as management reference points.

The relation of societal values and expectations to natural resources is complex. We know that social values and expectations exert pressures on the biological and physical capacities of ecosystems (Zonneveld 1988), but the effects are not well known. *Because of the transitional nature of public expectations, flexibility in future direction and conservation of future options are essential.*

Prescribing for Sustainable Ecological Systems

Ecosystem management requires a theoretical basis for ecosystem analysis and description, information on current forest conditions, and ecological reference points that describe potential sustainable conditions. Desired future conditions for landscape planning are defined in terms of ecological conditions that meet current human values without compromising future options. The prescription of sustainable states in ecosystem management requires:

- ❑ A theoretical base that recognizes temporal and spatial hierarchical landscape patterns, and the role of disturbance in creating and maintaining such patterns.
- ❑ The development of sampling designs and analysis methods applicable to multiple spatial and temporal hierarchies.
- ❑ A standardized classification of ecological landscape and stream classification units to facilitate extrapolation of information within and among analysis levels.
- ❑ Descriptions of historical ranges of variability for various landscape components and processes by ecological landscape or stream unit. This information is used as an initial template for sustainable ecosystem characterization.
- ❑ Definition of societal values and expectations for landscapes and ecosystems of an analysis area.
- ❑ Integration of sustainable landscape characteristics (patterns and processes) with societal values and expectations.
- ❑ Implementation of ecosystem management through the planning process.
- ❑ Monitoring for implementation, effectiveness, and validation of ecosystem management experiments.

Theoretical Basis for Landscape Ecology

Landscape heterogeneity results from abiotic factors (e.g., climate and landform), and biotic factors (e.g., successional processes and disturbance regimes) that operate at different spatial and temporal scales. Hierarchy theory allows nesting of one scale of pattern within another to organize landscape patterns and disturbances regimes into a coherent picture of causes and effects at different spatial and temporal scales. Pattern and process linkages between stand-, landscape-, and regional-scales are identified by this process.

Historical descriptions of landscape patterns and disturbances that maintained such patterns, provide an initial estimate of ecosystem sustainability. A knowledge of historical disturbance regimes, species composition, and landscape structures allows prediction of stand and landscape responses to disturbance and of the successional process of recovery. Such information is useful in describing the kinds, amounts, and spatial relations of various resource values within landscapes over time. *If existing landscape patterns and disturbance regimes closely follow historical conditions, the "coarse-filter" approach (Hunter 1991) to maintaining ecosystems suggests that biodiversity and long-term site productivity will be conserved.*

Landscape patterns determine habitat characteristics and availability of renewable natural resources (Baskerville 1985). An understanding of landscape ecology principles provides a basis for resource scheduling that considers spatial and temporal factors of ecosystem change. Recognition of the temporal and spatial nature of landscape patterns, and the agents responsible for their creation (biotic processes, disturbance regimes, and environmental constraints) is crucial to resource planning if sustainable flows of renewable resources are to be achieved.

Sampling Design and Data Analysis

Landscape evaluation and ecosystem characterization require recognition of pattern and environmental variable relations at various hierarchical scales. Pattern recognition is based on the premise that ecosystem components such as vegetation communities can be classified and delineated in patches along environmental gradients. Standardized databases and analysis systems are required for most characterization and evaluation efforts.

Ecological maps based on climate, landform, geology, soils, and potential plant communities (ecological units) do not change significantly following management activities: consequently, they provide a basic template for assessing current ecosystem conditions. Because the components used in delineating ecological units are stable over time, such maps are useful in defining biophysical environments for planning that have similar disturbance regimes, successional dynamics, and potential productivity.

Classification

A prerequisite to prescribing for sustainable ecosystems is the inventory and classification of landscape structure and composition. Ecological landscape mapping units allow the classification of landscapes into easily recognizable units that have similar topography, soils, potential vegetation, and response to disturbance. They also provide logical planning units because they are readily identifiable on landscapes, fit into a hierarchical landscape framework, and are useful in describing both current and potential characteristics of the land.

Hann and others, in this report, provide the following process for characterizing landscape and ecosystem attributes in a systematic manner for environmental analysis:

- ❑ Stratify the variability of the analysis area into broad ecological landscape units based on landform, parent material, and climatic criteria; describe the dominant ecosystem processes that cause change in ecosystem composition and structure by mapping unit.
- ❑ Further refine broad landscape units based on potential vegetation elevational zones.
- ❑ Develop historical records of vegetation pattern and disturbance regimes by potential vegetation zones.
- ❑ Synthesize potential vegetation zones and broad landscape units in describing ecological capability units for land-use planning.

Reference Points

Because natural ecosystem patterns are created and partially maintained by disturbance regimes, sustainability is not a static phenomenon but one of change within historical ranges of disturbance frequency, extent, and intensity. Maintaining disturbance effects within the historical range of variability is a useful conservation strategy for maintaining the biological diversity and long-term site productivity that was apparent before European settlement.

This conservation strategy, however, may not be appropriate to all management scenarios. For example, disturbance regimes that maintained historical ecosystems may not be appropriate in some currently altered ecosystems, and they may not be congruent with societal values and expectations. In these situations, the scale, intensity, and frequency of disturbances required to achieve desired social landscapes that conserve future options should be defined through an adaptive ecosystem management approach. *Historical disturbance effects are reference points not recipes.*

Several sustainable states may exist for a given ecosystem, that provide different landscape characteristics and flows of renewable resources. The current understanding of sustainable states, however, only includes those that fall within the range of historical landscape patterns and disturbance conditions. Other landscape patterns and species compositions may be sustainable, but no supportive information is available for their description at this time.

Integrating Landscape Ecology with Social Needs

Sustainable ecosystems are the integration of societal expectations with land potentials, technology, and economic factors (Figure 2). An understanding of historical and existing landscape patterns provides a means of integrating societal values and expectations with land capabilities.

Ecosystem management can best maintain ecosystems in conditions compatible with natural processes and human values by recognizing that ecosystems are not static, but instead change following disturbance. *Rather than focusing solely on conserving existing landscape patterns in implementing ecosystem management, conservation can also be achieved by maintaining disturbance effects that created premanagement-era landscape patterns and successional pathways. Additionally, the mimicking of natural disturbances through management actions provides opportunities for sustainable flows of resources in balance with historical ecosystem conditions.*

Information on Eastside Forest Ecosystems

Although, we have the theoretical, analytical, and managerial tools to prescribe for sustainable ecosystems, in reality, prescribing for sustainable ecosystems in eastern Oregon and Washington is limited by one or more of the following information needs:

- ❑ An information base that characterizes landscape patterns, their spatial and temporal features, and the disturbance effects that created and maintained them.
- ❑ An understanding of successional dynamics and the characteristics and time frames for vegetation recovery after disturbance.
- ❑ Knowledge of what society values and expects of its National Forest lands, and the ability to articulate that vision in ecologically sustainable landscape patterns and disturbance effects.

In eastern Oregon and Washington, knowledge of current and historical conditions and disturbance regimes is lacking. The 1.1 million-acre sample area analyzed by the Assessment Team (Volume III) provides a first glimpse at existing and historical landscape patterns and disturbance processes across various ecoregions of eastside forests. Ecosystem management, however, is a landscape-by-landscape process and requires an information base on all lands that are to be managed for sustainable ecosystems.

Monitoring

Monitoring is a cornerstone of adaptive ecosystem management; it is needed to continuously evaluate management goals, ecosystem processes, and achievement of management objectives. Monitoring must occur simultaneously at multiple temporal and spatial scales.

Monitoring for static levels of species, structures, or habitats has been the norm in the past, but increased emphasis should be place on monitoring for acceptable change within specified ranges. Because disturbance events maintain landscape characteristics, it is essential to know if the frequency, extent, and intensity of historical disturbance effects are maintained by natural or man-induced processes.

Case Studies

Prescribing for sustainable ecosystems using an ecosystem management approach requires preliminary testing on the ground. Caraher and others (1992) successfully used the ecosystem management approach of the USDA Forest Service (1992a), to identify eastern Oregon landscapes that were outside their natural range of variability for vegetation types, and made recommendations for their restoration. O'Hara and others (Volume II) developed landscape hierarchies that were used to compare current and historical ranges of variability in vegetation in studied landscapes of western Montana. "Desired future conditions" were developed for all major biotic, abiotic and social resources in the analysis areas studied (forests of western Montana). These pilot projects and others demonstrate that landscape ecology principles can be incorporated into land management planning and project design.

Question 3: Are eastside ecosystems in Oregon and Washington stressed and in need of restoration?

(References: Volume III, IV)

The available evidence shows that some eastside ecosystems are stressed and unstable (the recovery period is greater than the disturbance period). Based on the scientific literature, knowledge of the processes that regulate ecosystem structure, composition, and functioning, and a quantitative assessment of change in a representative sample of land and aquatic ecosystems in eastern Oregon and Washington, some management practices of this century have reduced diversity (genetic, species, and landscape) and long-term productivity (soil, water, and air), and have thereby diminished the capacity to ensure a sustainable flow of renewable resources. Landscapes and ecosystems need to be restored when ecological structures, processes, or flows essential to sustained diversity and productivity are impaired or disabled, and natural recovery is not likely in an acceptable time frame or by an acceptable pathway. Some eastside ecosystems have been altered by management to an extent that recovery of diversity, productivity, and disturbance effects to a standard consistent with societal expectations is only possible with immediate corrective actions.

Threats to Eastside Ecosystems

Significant threats to genetic, species, and landscape diversity, and long-term productivity are apparent on the east side of Oregon and Washington. *Highly diverse ecosystems are adaptable to change, and they yield the widest range of choices to managers considering alternative futures.* Diversity of present-day eastside ecosystems is threatened by:

- ❑ Intensified or altered disturbance regimes (fire, insect, disease, flood, grazing);
- ❑ Acute reductions in quantity and quality of some land and aquatic plant and animal habitats;
- ❑ Acute reductions in populations of some land and aquatic plant and animal species; and
- ❑ Significant discontinuities in some land and aquatic plant and animal habitats.

Soil, water, and air are the growth media for land and aquatic plants and animals. The properties of these media are changeable. All plant and animal species have specific requirements for growth, survival, and reproduction involving one or more of these media. Management-induced changes in soil, water, and air properties and their interactions, can profoundly influence plant and animal habitats. Long-term productivity of present-day forest, rangeland, and aquatic ecosystems is threatened by:

- ❑ Intensified or altered disturbance regimes (fire, insect, disease, flood, grazing);
- ❑ Soil erosion and mass movement events;
- ❑ Damage to soil structure, density, and nutrients, and microbial and developmental processes;
- ❑ Reduction in water quality and yields;
- ❑ Alterations to soil, water, and air chemistry; and
- ❑ Damage to riparian habitats and side slopes.

How Did Eastside Ecosystems Get This Way?

People changed them. For millennia, people have been changing Oregon and Washington ecosystems to suit their cultural needs. The century-and-a-half of European settlement is but one more episode in a continuing chronicle of people manipulating their surroundings. Management practices of this century were an outgrowth of previous societal values and expectations. Societal expectations have changed again recently favoring ecological and amenity values in addition to consumptive uses. Prior human inhabitants lacked the sophisticated machines and technology to rapidly modify their environments as we have, although Native American burning left a significant mark on eastside ecosystems.

It would appear that the technology and population pressures of this century have brought about the most sweeping changes ever occurring in this region, but that is probably not the case. The mixed coniferous forests we observe today are of recent derivation, resulting from a period of moderating climate. In the Pacific Northwest, change in vegetation due to climate flux, volcanism, glaciation, or post-glacial recession is ordinary rather than extraordinary.

We evaluated the effects of nine management practices identified by the science panel (appendix A) on eastside forests, rangelands, rivers, and streams. Those practices include:

- Effective fire prevention and suppression;
- Selective timber harvesting and tractor logging;
- Grazing by livestock and wildlife;
- Pest suppression;
- Roading and access management;
- Fuels management;
- Custodial land management of wilderness, wildlife habitat areas;
- Mining and waste disposal;
- Flood control and irrigation water withdrawal.

We found solid evidence that most management practices were applied to objectives that were inappropriate to conserving biodiversity and long-term productivity.

Restoring Affected Ecosystems

To return eastside ecosystems to a sustainable condition, disturbance effects, biological diversity, and long-term productivity should be restored to historical ranges of variability.

Restoring Disturbance Effects

Disturbance regimes need to be returned to historical ranges when disturbance frequency, intensity, or scale have been significantly modified. In this eastside assessment, the effects of several disturbance regimes were identified as requiring restoration:

- ❑ Fire regimes;
- ❑ Defoliator and bark beetle outbreaks;
- ❑ Root disease and dwarf mistletoe epidemics;
- ❑ Grazing (cattle, elk, sheep, horses);
- ❑ Hydrologic regimes (storm flows, low flows, total yields).

Disturbances are important to creating and maintaining terrestrial and aquatic habitats. In terrestrial landscapes, disturbances provide heterogeneity in patch size, patch composition and structure, and often in susceptibility to future disturbances. Sampled wilderness watersheds of eastside river basins (Volume III) became more homogeneous when fires were excluded. Historically, defoliating insects and tree-killing bark beetles increased the contrast between forest patches, providing standing and down woody structural habitat for insects, birds, and mammals. Dead trees also provided habitats for natural enemies of major defoliators. Insect outbreaks typically produced stand- and watershed-scale effects.

In aquatic ecosystems, floods are responsible for creating and reviving freshwater and anadromous fish habitats, habitats of freshwater plants and invertebrates, and small freshwater mammals. Historical streams had some capacity to buffer all but the most severe floods. In the low grade stream reaches, side channels were connected or accessible to streams; these acted as overflow reservoirs during floods. Historical streams freely meandered in the low grade reaches which functioned as important habitat areas often undergoing considerable change during and after floods. Today, forest roads, highways, and stream channelization prevent this ongoing and important evolution in stream sinuosity.

Fire Disturbance Regimes

In this century, fire frequency has diminished through effective prevention and suppression programs. Highly flammable understories have developed over vast areas of eastside forests, providing vertical and horizontal continuity to fuels. Increases in fuels from tree mortality caused by insects and diseases combined with green fuel ladders have transformed areas that were historically low to moderate in severity of fire disturbance into areas with potential for severe fires. Underburning, once common, is now unlikely; instead, current fuel accumulation and continuity suggest that most future fires will be large-scale, damaging events.

> *The ecological influences of frequent fires of low to moderate intensity should be returned to all landscapes with historical fire regimes of low to moderate severity. This includes most forested landscapes of the ponderosa pine, Douglas-fir, and grand (white) fir series, and some landscapes of the subalpine fir series. Some influences can be mimicked and methods alternative to fire may be employed. Other effects of fire cannot be mimicked necessitating the use of managed fire at some point.*

It is likely that Indian burning practices increased fire frequency well above natural ignition frequency in many low- and mid-elevation landscapes. The probable influence of increased fire frequency was improved ecosystem robustness and stability through:

- Improved fire tolerance of landscapes—frequent fires favored fire-tolerant species and elevated tree crown bases;
- Wider tree spacings;
- Improved forage conditions—frequent fires increased abundances of shrubs, grasses, and forbs in understories and open areas;
- Improved tolerance to forest pathogens and insects—frequent fires favored the dominance of seral species in the forest matrix;
- Improved landscape and species diversity.

Defoliator Disturbance Regimes

Outbreaks of conifer defoliators are currently more threatening to resources, and more influential to habitat conditions than in presettlement times. The western spruce budworm and the Douglas-fir tussock moth are native to eastside forests, but their current level of influence is apparently unprecedented. Stands of susceptible hosts are more continuous, and susceptibility in host patches has also increased. A six to seven year drought period has significantly amplified the effects of current outbreaks. Stands are dominated by shade-tolerant species, and hosts are layered.

> *Defoliation severity and duration should be returned to historical ranges of variability by managing landscape mosaics of the Douglas-fir, grand (white) fir, and subalpine fir series to mirror historical vegetation patterns, composition, and structures.*

In practical terms, this prescription means that landscapes that were historically underburned with high-frequency, low-intensity fires should be dominated by well-spaced seral stands. Landscapes that normally burned with moderate frequency should be mixed in composition. Landscapes that typically burned with low-frequency, high-intensity fires should be managed primarily as multi-layered, late-seral, and climax stands with shade-tolerant species dominating. This adjustment of landscape patterns and composition reduces fire hazards both in scale and intensity, as it adjusts defoliator effects to ecologically sustainable levels.

Bark Beetle Disturbance Regimes

The effects of native bark beetles currently devastating to eastside forests are elevated by effective fire suppression and prevention. Bark beetle effects historically occurred at stand- and watershed-scales prior to European settlement; today, larger areas are impacted. Ponderosa pine stands once widely spaced by regular underburning, have become multi-layered, overstocked, and often heavily dwarf mistletoe-infested. Tree-killing bark beetles cue on stressed trees, usually thinning stands from above. Often entire stands or groups of stands are killed.

Severity and duration of pine bark beetle outbreaks should be returned to historical ranges of variability by greatly reducing stocking, and increasing spacing in ponderosa pine stands. Optimal spacings are those that factor in climatic extremes and are not based on average conditions.

Lodgepole pine stands were historically regenerated after bark beetle outbreaks and stand replacement fires. Current bark beetle outbreaks in lodgepole pine are typically more extensive and last longer. Lodgepole pine ecosystems present a real opportunity to manage bark beetle hazard, depending on ecosystem management objectives. If tree mortality produces desirable habitat, susceptible conditions can be preferred by prescription. Likewise, if beetle hazards are to be minimized, technology is available to do so.

Root Disease Disturbance Regimes

Four root pathogens are responsible for most of the root disease in eastside landscapes. Two root diseases (Armillaria root disease and laminated root rot) have increased from historical centers or foci, to their current distribution. One root disease (S-group annosum) has increased very rapidly throughout the grand (white) fir series as a result of decades of partial cutting and fire exclusion. Another root disease (P-group annosum) has increased in numerous areas within the dry ponderosa pine series, also in response to widespread selective harvesting. Today, the scale and intensity of root disease disturbance is considerably greater than occurred historically.

Root disease incidence and severity should be returned to historical ranges of variability by managing landscape mosaics of the ponderosa pine, Douglas-fir, grand (white) fir, and subalpine fir series to mirror historical vegetation patterns and fire disturbance effects. Root disease increases in the ponderosa pine series will not be readily reversed.

Recommendations for defoliators should restore root disease influence to ecological sustainability.

Dwarf Mistletoe Disturbance Regimes

Dwarf mistletoes infest more than 40 percent of all coniferous stands on the eastside. Collectively, dwarf mistletoes cause more tree growth and mortality losses than all other pests. Selective harvesting and fire exclusion have created densely stocked, multilayered stands that are ideal for rapid spread and intensification of mistletoes.

Incidence and severity of dwarf mistletoe should be returned to historical ranges of variability by managing landscape mosaics of the ponderosa pine, Douglas-fir, grand (white) fir, and subalpine fir series to mirror historical vegetation patterns and fire disturbance effects.

Ecosystem management practices that simplify canopy structure to a single layer, and regularly eliminate the most severely infected trees mimic the historical role of underburning fires. Management practices that completely regenerate infested stands mimic the role of stand replacement fires.

Grazing Disturbance Regimes

Grazing disturbance has always been a part of eastside ecosystems, but grazing effects prior to the introduction of domestic livestock were minimal and not concentrated in lowland areas during the growing season. Regular underburning maintained open forest conditions in the low and middle elevations, and browse species were abundant in open grassland and meadow areas, and under open forest canopies. Horses, cattle, sheep, and other domestic livestock were introduced to eastside forest and rangeland ecosystems in the late 1800s. By the turn of the century, damage to open range was already noticeable, and by

the 1920s and 1930s, there was considerable evidence of rangeland degradation by sheep and cattle. Sustainable grazing levels may be much lower than are currently prescribed if degradation of forest, rangeland, and riparian ecosystems is to be avoided. Degradation comes in many forms:

- ❑ Soil loss through erosion, mass movement, stream bank instability;
- ❑ Reduced water quality from erosion and streamside grazing;
- ❑ Altered species composition and loss of native annual and perennial species;
- ❑ Invasion of noxious weeds and other non-native species;
- ❑ Loss of shrub and herbaceous vegetation by overgrazing;
- ❑ Encroachment of forest and woodland tree species;
- ❑ Damage to soil structure, nutrient status, and moisture-holding ability; and
- ❑ Damage to forest and rangeland riparian vegetation and soils.

> *Grazing disturbance should be adjusted to rates that conserve or restore the diversity of both forage and nonforage species, conserve or restore long-term site productivity, and ensure a sustainable flow of renewable range resources. This objective can be accomplished by managing forest and range landscape mosaics that are consistent with historical ranges of variability in disturbance regime and vegetation pattern. The mix and numbers of grazing species should be adjusted to be compatible with all ecosystem structures, processes, and flows.*

This will mean in all likelihood that society must choose between sustainable rangeland ecosystems and maintaining the amount of grazing currently allowed.

Hydrologic Disturbance Regimes

Historically, natural hydrologic disturbances (storm flows, peak flows, low flows) were important to creating and maintaining riparian and aquatic habitats. Today, all but the worst peak flow events are mitigated by dams, water impoundments, irrigation diversions, and road systems. In fact, road networks have become major drainage routes. Most disturbances affecting river and stream habitats today are associated with other land use activities.

Prior to European settlement, streams, their floodplains, and riparian zones buffered all but the most extreme hydrologic events. When considering streams and their ecological sustainability, it is essential to consider riparian ecosystems and floodplain areas as integral parts of these aquatic ecosystems. Riparian zones not only buffer streams from upslope disturbance influences, they also provide vegetative material (logs and other debris), and shade essential to fish habitats. Floodplains provide overflow areas during flood events dissipating the energy of flooding streams, trapping sediment, and reducing the scouring effect of storm flows on stream bottoms. Stream bottom scouring occurs when stream channels are separated from their side channels and floodplains, and storm flows are channeled down the main stream channel. When streams are allowed access to their floodplains (roads and other structures are not limiting), they are free to meander and regenerate or recreate their habitats.

Hydrologic disturbance regimes should be returned to historical ranges of functioning and variability by managing stream channels, riparian zones, and side slopes as an integrated system. Hydrologic disturbance processes should be operating within acceptable ranges when riparian vegetation composition and structure, stream channel and floodplain morphology, and hillslope water percolation, infiltration, and erosion rates are within historical ranges of variability.

Assessments of conditions and restoration needs should be made for all eastside watersheds. Assessments should be designed according to an understanding of the geology, geomorphology, soils, climate, and vegetation of each watershed.

Maintaining Biological Diversity

Adaptability to change (changing climate; changing environment for growth, reproduction, and survival; changing disturbance regimes; catastrophic events; and continuously changing human social systems, values, and expectations) comes from diversity of species, and diversity of habitats. For maximum adaptability, no species or habitats are expendable. When some species are considered expendable, the unstated intention is to manage for declining ecosystem adaptability, and a declining number of management options. Choices such as these are biologically unacceptable because they lead to ecosystems that are less robust. Conservation of options for the benefit of future generations which is part of the definition of ecosystem management (Overbay 1992), explicitly suggests that all species contribute to ecosystem sustainability, and that management-induced extirpation is unacceptable.

When threatened, endangered, and sensitive species are listed, that is a direct barometer of management failure to maintain ecosystem adaptability to change. When species are delisted, that is a measure of success in maintaining species viability and ecosystem integrity. At the present time, there are a number of threatened, endangered, or sensitive fish, plant, avian, mammalian, fungal, or arthropod species that are near the margin of viability. In plain language, this means options may have already been foreclosed on decisions of future generations.

Plant and animal species viability should be maintained and habitat diversity restored to the extent possible, to historical ranges of variability. This goal can be partially accomplished by using a coarse-filter management approach for all forest, range, and steppe landscape mosaics, and all aquatic ecosystem. Where species viability has already been compromised, fine-filter conservation strategies will be needed to maintain viability.

Because conflicts occur between coarse- and fine-filtered approaches, compromises must be made to minimize loss of species and to maximize species and habitat recoveries, restore essential effects of disturbances, and restore soil, air, and water productivity. Compromises alone will not solve many problems, though; and may even compound hazards. When goals are conflicting, hard choices will have to be made.

Restoring Long-term Productivity

Soil productivity of any ecosystem is a function of its chemical, physical, and biological properties. Conservation strategies for soils should include maintaining soil organic matter, bulk density, nutrients, structure, water-holding capacity, microbial processes, and soil arthropods. Conceptually, this effort may sound rather simple, but it is highly complex in practice.

In the ponderosa pine series, soil productivity depends on conserving organic matter, surface soil nutrients, and soil moisture, and on minimizing soil disturbance, compaction, and surface erosion. Soils of the Douglas-fir, grand (white) fir, and subalpine fir series are either derived from volcanic ash or are strongly influenced by ash. They have relatively high water-holding capacities, are well aerated, and have low bulk densities, allowing rapid water infiltration. Long-term soil productivity hinges on avoiding compaction and surface soil displacement. Soils of the lodgepole pine series generally have readily available water storage, low bulk densities, and moderate to low fertility. Long-term productivity depends on conserving soil fertility and soil organic matter.

Some damage to soil productivity is irreversible. Other effects are reversible but only over long periods. Areas with special soil conservation needs should be identified and managed according to those special needs to avoid further losses and to obtain the best restoration practicable under constraints of technology and funding.

> *Soil productivity of all eastside ecosystems should be restored to historical ranges of functioning and variability by inventorying soil conditions across ecosystems, according to essential and limiting properties, to determine restoration priorities. Restoration activities should address those soil properties that fall outside historical ranges.*

The long-term productivity of aquatic ecosystems likewise depends on conserving the essential properties of water such as temperature, chemistry, purity, and yields, and on conserving aquatic habitat types (pools, riffles, side channels, spawning beds) and habitat structural elements (logs, boulders).

> *Water quality and aquatic habitats should likewise be restored to historical ranges of functioning and variability. Water quality and aquatic habitat conditions should be inventoried for all eastside streams to determine restoration needs and priorities. Restoration activities should consider stream channels, riparian zones, floodplains, and side slopes as part of a single, highly integrated system. Activities in these adjacent areas should cooperate with and enhance restoration activities.*

Restoring a Sustainable Flow of Renewable Resources

The return for investing in restoration and maintenance of sustainable ecosystems is the sustainable flow of renewable resources. Extractive and consumptive resource uses should be consistent with the location, scale, pattern, and effects of historical disturbance regimes (fires, insect outbreaks, and disease epidemics). For example, presettlement forest fires destroyed stands of timber, killing trees in small patches, or large areas. Trees were killed but not removed by fire and a considerable biomass of dead wood was left standing. Before being incorporated into the soil, these dead trees functioned first as dead shade—moderating site conditions for the establishment of new conifer seedlings, shrubs, and herbs; snags—providing food, roosts, and homes for various birds and small mammals; and down logs—again providing food and shelter, and substrate for arthropods, plants, soil bacteria and fungi, and moisture retention.

Dead trees and down logs play important roles in ecosystems. An important goal of research will be to determine the amount of dead wood that is needed to conserve biological diversity and long-term productivity. An important goal of ecosystem management will be to match management actions to the disturbance ecologies of ecosystems. Timber harvesting and prescribed burning at the appropriate scale, using appropriate techniques, can be useful tools for ecosystem management, but yield expectations for harvested acres should be scaled to accommodate the dead wood needs of ecosystems.

The scale, intensity, and frequency of historical fire, insect, and disease disturbance regimes should determine the pattern, composition, density, and structure of eastside vegetation until alternative sustainable landscape designs can be validated. Small harvest units are not an acceptable substitute for high severity fire events that historically destroyed hundreds and thousands of acres. Years later, these same catastrophic events yielded large, continuous forests in future decades that exhibited interior forest qualities desired by many wildlife species. Large scale regeneration projects can be successfully implemented to mimic such events, and they can be implemented in stages over decades to minimize visual impacts. Large amounts of standing and down dead wood should be left after harvest. Timber harvest should be considered as one of the methods used to disturb ecosystems, rather than as an end in itself.

Large harvest units are not an acceptable substitute for high frequency, low intensity fires. For there to be a sustainable flow of renewable resources, it will be important to match the silvicultural methods used with the landscape pattern that is desired.

Similarly, thoughtful use of various harvest techniques and managed fire can minimize insect and disease hazards in the same way that diseases and insects restored stability to historical ecosystems as they became unstable. For example, frequent underburning thinned ponderosa pine stands, maintaining fairly wide spacing. Portions missed by fires became overly dense, and tree vigor declined in those pockets until they were thinned or destroyed by bark beetles. Under ecosystem management, planned thinning can leave behind important dead and down wood in all of its needed forms.

Finally, managing the pattern of seral stages across landscapes within historical ranges of variability is important to maintain an appropriate mix of habitats for all the known and unknown species native to eastside ecosystems. This strategy is the basis of the coarse-filter approach. Historical patterns were determined by the unique disturbance ecology of each ecosystem. Management should now attempt to reproduce those patterns and outcomes until other alternative sustainable states are experimentally validated.

Question 4: What are the effects of management practices on ecosystem sustainability? What changes are needed in current management practices? What are the knowledge gaps that prevent adequate evaluation of current management practices?

(Reference: Volume III)

Introduction

The ecosystem management philosophy for National Forests focuses on three broad goals (Overbay 1992): (a) conserving biodiversity, (b) conserving long-term site productivity (soil, water, and air), and (c) providing a sustainable flow of renewable resources. The Forest Service is already legally responsible for conserving biodiversity (Endangered Species Act) and maintaining site productivity and a sustainable flow of renewable resources (National Forest Management Act). Appropriate management systems, internal organizations, and field operations are needed to achieve these goals. *Few field operations are either universally beneficial or damaging to ecosystems or landscapes; field operations can be deleterious to ecosystems, however, when they are done at the wrong time, place, or scale or are applied to achieve inappropriate objectives.* Determination of the correct timing, location, and scale of field operations is based on clearly articulated local and regional landscape management goals, quantifiable objectives, and interdisciplinary planning. Management practices are currently available to effectively manage landscapes and ecosystems. How these practices can be used in landscape prescriptions for ecosystem management will be discussed. "Management practices" refers to both planning and implementation of field operations to achieve long- and short-term management objectives.

Management Goals Must Be Clear and Unambiguous

Management goals must be clearly articulated and expressed in terms of effort, risks, benefits, costs, and trade-offs. Management practices cannot be applied to achieve contradictory goals. Management practices must find the common ground between conflicting laws to be successful, and various scales of planning should highlight where laws are ambiguous in their intent or in conflict with other laws or legal mandates. Conflicting or ambiguous goals must be clarified before effective planning can begin.

Management Systems and Organizational Requirements

A management system is used to translate management goals into specific field operations to achieve them. The system integrates knowledge of societal preferences, natural sciences, social sciences, technology, and existing infrastructure with on-the-ground conditions. A management system is established to provide a logical flow of information for analysis, decisions, and management actions to ensure that goals are achieved. The organizational structure must match the goals of ecosystem management. The structure must be flexible and assure that decisions are made at the appropriate organizational level and with societal and scientific participation.

Management Operations

Field operations are the tools of the land manager and like most tools, they are neutral in intent. When a carpenter builds a house, it is not the tools but the house plans and building materials that determine the type and quality of the house that is built. The carpenter recognizes the strengths and limitations of each tool in his tool bag and uses each one accordingly. Society is now asking for a new blueprint for public landscapes, which should result in new designs for more sustainable landscapes and more appropriate applications of some existing management tools. New tools will also be needed to achieve landscape-scale objectives, such as reconfiguring the pattern of seral stages, reducing fire or defoliator hazards, or rehabilitating riparian zone vegetation and flood plains. Clearly, prescriptions must describe management of landscape structure and composition; the management unit is the landscape, not the stand.

Forest Management Practices Were Implemented in Highly Altered Ecosystems

Eastside ecosystems have experienced continual change in species composition over the last 20,000 years. Fires, frequently set by Native Americans, altered natural states of ecosystems and redefined landscape configurations that were more suitable to their cultures. Early European settlement of eastern Oregon and Washington was marked by heavy livestock grazing, heavy use of fisheries, water withdrawal for irrigation, mining, selective tree harvesting, and the intentional suppression of frequent low-severity fires. Against this backdrop of already altered ecosystems, the Forest Service implemented a commodity-oriented management system in the 1940s.

What follows is a summary of the documented effects of that management system on ecosystem sustainability. Effects are expressed in terms of influence on biodiversity, long-term productivity, and sustainable resource flows. Effects are either short- or long-term, and they vary in extent and intensity. The effects of management practices[1] on eastside terrestrial and aquatic ecosystems are discussed in detail in Volume III. Another panel of scientists (appendix A) was also consulted to provide additional technical insights to the effects of management practices.

[1] Management practices were identified and selected from a larger list by a panel of scientists from a variety of disciplines representing State and Federal land management agencies and universities—September 1992.

Fire Prevention and Suppression

Fire suppression had its greatest effect in disrupting fire regimes of high and moderate frequency and of low and mixed severity characteristic of ponderosa pine, Douglas-fir, and grand (white) fir climax series. Because of fire suppression, many areas have an overabundance of trees. Understory tree cover of shade-tolerant species has increased significantly in most watersheds in eastern Oregon and Washington, and stocking typically is in excess of site potential. Such overcrowding stresses trees and predisposes them to insect and disease attack. Dead trees in contiguous, overcrowded stands contribute to high fuel loadings, and vertical and horizontal fuel continuity. Areas where fire has been excluded also have much higher potential for smoke production because of higher fuel loadings.

Effective fire prevention and suppression programs ultimately have the undesirable effect of intensifying fire severity, and drastically lengthening recovery periods after fires. Prevention and suppression efforts also disrupt normal fire cycles and associated nutrient and biomass cycling. Recent research indicates that extended periods without fire result in increased above-ground nutrient accumulations. Above-ground nutrient capital is at increased risk during severe fires and after, when rainfall is heavy. Significant soil losses have been reported after heavy rains on burned forest lands (Helvey and others 1985). Increased prescribed burning has been proposed in the Blue Mountains (U.S. Department of Agriculture 1993); however, efforts are limited by smoke management concerns, which are driven by State air-quality standards.

Selective Timber Harvesting and Tractor Logging

Stand and landscape characteristics have been significantly altered by selective harvesting, high-grade logging, and overstory removal operations in this century. Ponderosa pine was extracted first because it was preferred for a variety of forest products. Douglas-fir, western larch, and grand fir were harvested next when ponderosa pine was less easily obtained. Selection of the largest trees for timber harvest may have reduced the genetic diversity of some residual stands. Timber harvesting practices in eastern Oregon and Washington have increased the potential for higher rates of fire spread and intensity. Additionally, some intensively managed watersheds have become more diverse and fragmented, while other wilderness watersheds have become less diverse and are less fragmented.

Timber harvesting and fire suppression have greatly modified the pattern of eastside structural stages. In most watersheds, there has been a significant reduction in the abundance of old late-seral park-like and old climax forest stands. In others, there has been a significant reduction in young sapling and pole stands. Most watersheds have seen a great increase in area of middle-aged stands. Timber harvest practices and fire suppression have caused conspicuous shifts away from early-successional to late-successional species in understories as well as overstories, and overcrowding is widespread. Insect and disease hazards have increased in some watersheds and decreased in others. Major shifts in insect or disease hazard in either direction are usually cause for concern because of the essential disturbance roles of these agents.

Soil compaction and nutrient losses from erosion or fire have also been associated with past timber harvest practices. Most log yarding on slopes less than 40 percent has been accomplished using crawler-tractors and rubber-tired skidders. Soil compaction and soil displacement have been the primary detrimental effects. Machine piling of logging slash has contributed substantially to soil displacement and compaction in some areas. Regional guides to limit soil disturbance and compaction during tree harvest should alleviate some of these concerns in the future.

Grazing by Livestock and Wildlife

Concern about the continued productivity of grazing lands under unlimited grazing prompted early livestock operators in Oregon to request Federal intervention to protect the rangeland resource. Grazing allotments were established to control and monitor grazing on public lands, but recent reports (U.S. General Accounting Office 1988, 1990) indicate that, nationally, 70 percent of allotments are not meeting management objectives, and 25 percent are declining (U.S. Department of Agriculture 1992b). In eastern

Oregon and Washington 53 percent of allotments are not meeting management objectives (Richard Apple, Pacific Northwest Region, personal communication with R. Everett). Grazing effects are often most severe in riparian areas, with resulting degradation of fish habitat. Nationally, rangelands occupy over 50 percent of Forest Service-administered lands, yet receive only 1 percent of the budget. This trend of declining rangeland quality will likely continue as long as this funding disparity exists.

Grazing by livestock can improve forage quality for elk, but combined wildlife and livestock grazing may adversely affect basic soil and forage resources. Grazing has been linked to significant decline in fish habitat. Grazing and the loss of plant cover are associated with increased rates of erosion. Soil losses further decrease the amount of plant cover, and erosion again increases.

Pest Suppression

Spraying for conifer defoliators began in eastern Oregon and Washington in the 1940s to suppress outbreaks and reduce tree mortality. The microbial insecticide B.t. *(Bacillus thuringensis)*, and the chemical insecticide carbaryl, are used today to suppress these needle-eating insects, but effects on populations are limited to two or three growing seasons. Defoliator outbreaks are occurring with historical regularity, but with increasing intensity and duration, and there are currently large western spruce budworm outbreaks in eastern Oregon and Washington, and an outbreak of the Douglas-fir tussock moth in eastern Oregon. Defoliation hazard has increased over historical levels in watersheds of all sampled river basins in eastern Oregon and Washington. Combined pest management and vegetation management practices, therefore, are less than fully successful. Insect outbreaks are an important part of eastside ecosystems, however, and their complete absence would also be grounds for concern.

Defoliator suppression maintains current forest structures and reduces the short-term effects of extreme outbreaks, but it also disrupts normal insect disturbance regimes and may affect nontarget species. Pest suppression alters nutrient cycles and can contribute to conditions that ultimately result in net nutrient depletion after severe fires.

Both fire and pest suppression may be required in some areas to maintain site nutrient capital until dysfunctional systems can be returned to more sustainable states. Managed fire and other vegetation management practices can stabilize nutrient cycles and prevent severe fires that could cause off-site transport of nutrients.

Roading and Access Management

About 57,000 miles of National Forest System roads currently exist in eastside forests of Oregon and Washington. Roading has been linked to negative effects on wildlife habitat, fish habitat, soil stability, and water quality. Roads reduce site productivity in the roaded area and can accelerate erosion, reduce water quality, and increase siltation. Roading also aids in fire prevention, recreation access, and flow of resources. The current "Access and Travel Management" process of the National Forest System suggests that as many as 19,000 miles of road may no longer be needed in eastside forests. The immediate challenge is to maintain acceptable recreation, resource management, and fire management access while optimizing new landscape and habitat configurations.

Fuels Management

Some prescribed burning of timber harvest slash has adversely affected many soil processes and air quality. Less-severe burn prescriptions have been developed recently that consume less forest litter and have reduced smoke emissions (Little 1990). Smoke production from prescribed burns was estimated to be nearly half that produced by wildfires in a sampled watershed in the Grande Ronde River basin. Prescribed burning programs historically have been limited in their extent and were inadequate to keep pace with fuel buildup caused by fire suppression. Mutch and others (1993) recommend prescribed burning on ten times as many acres as are presently burned each year to reduce fuel loadings and landscape fire hazards.

Fuels management through prescribed burning provides one means to reintroduce the effects of fire and to recapture some of the historical landscape heterogeneity and stability. Thus far, concerns for air quality have made reintroduction of fire difficult to accomplish on a large scale. Severe burns, however, can cause significant losses to site nutrients through increased erosion and volatilization of nutrients.

Custodial Management of Wilderness and Wildlife Habitat Areas

Custodial management has been the standard approach to protect scenic areas, unique resources, habitats, and species. This approach would work well if stands and landscapes remained static, but they do not. Eastside ecosystems reflect great variety in insect, disease, and fire disturbance regimes. Custodial management with fire suppression creates the same fire and insect hazards as in more intensively managed landscapes, ultimately jeopardizing the original intent of conservation by changing the scale, intensity, and duration of disturbance events.

Custodial management is a desirable short-term strategy for conserving unique species or habitats but may not be a successful long-term approach in dynamic ecosystems. Custodial management may enhance biodiversity in late-successional stages, but at a cost to diversity of whole landscapes; in time, the abundance, kinds, and distributions of early- and mid-successional stages and species decline. This pattern was clearly observed in the assessment sample of eastside watersheds. Custodial management contributes to reductions in soil, water, and air productivity and biodiversity if normal disturbance regimes are significantly modified.

Mining and Waste Disposal

Mineral mining activities have fluctuated widely in the past half century. The effects of previous placer and hydraulic methods, leachates from deposits of lode mining, and bucketline dredges continue to influence stream and riparian ecosystems. More recent mining effects to aquatic systems come from leach mining for gold and gravel mining from stream channels and flood plains. Historical mining practices did not commonly conserve diversity or site productivity of streams or riparian areas. Future mining reclamation activities should be designed to restore affected landscapes to conditions within the range of historical variability.

Flood Control and Irrigation Water Withdrawal

Removing water from streams for irrigation and municipal water supplies adversely affects fish habitats, riparian ecosystems, and associated wetlands. Irrigation use has expanded in eastern Washington and Oregon, and increased conflicts over limited water are anticipated.

Water withdrawal for irrigation does not conserve diversity or site productivity of streams or riparian areas; however, concentration of food production on fewer acres through irrigation does minimize agricultural impacts on forested areas.

Difficulties in Interpreting the Effects of Management Practices

Interpreting the effects of management practices on biological diversity and long-term site productivity is complicated by differences in short- and long-term effects, objectives, and the timing and extent of practices. Management practices can be evaluated according to actual effects but differing circumstances and management can increase both adverse and beneficial effects.

Providing a Sustainable Flow of Renewable Resources

Management practices discussed above were historically implemented on the east side to provide flows of renewable and nonrenewable resources to the public. Considerations of biological diversity and site productivity were minimal until recently. Society clearly has values and expectations that are satisfied by the continual flow of renewable resources. Adaptation of some management practices to conserve biodiversity and maintain long-term site productivity has occurred within the last decade. Sustained flow of renewable resources from public lands is now based on restoring and maintaining sustainable ecosystems.

Management Practices to Create New Landscape Patterns

Timber harvest and prescribed burning practices can greatly modify stand structures and, thereby, landscape pattern and composition. To some extent, the experience with those patterns has been negative for society and for some associated plant and animal species. Management objectives were achieved through silvicultural prescriptions designed for individual forest stands with little regard for landscape structure and composition. Many of the same methods can be used if they are designed to meet landscape objectives. The goals of landscape prescriptions should be clearly articulated according to desired and essential landscape attributes.

Each landscape should be considered unique and have an original design, but experience with related landscapes and patches will provide increasing insight for subsequent landscape designs. When landscape units are inventoried and classified, as recommended in Volume II, considerable insight and design experience can be shared among similar landscapes. The quantified objectives of landscape prescriptions should be consistent with the biological and physical capacities of landscapes, fully considering historical disturbance regimes and their effects, potential vegetation, historical probabilities for disturbance outcomes, local soils, hydrology, geomorphology, and past management effects.

Silvicultural objectives for landscapes should address the landscape pattern of successional and structural stages; density; abundances of early-, mid-, and late-seral species and their arrangements; patch sizes and edge complexity; placement of adequate woody debris and snags as long-term and short-term habitats; long-term nutrient cycling and soil moisture retention needs; conservation of soil and water productivity; long-term smoke emissions; and landscape habitat connectivities.

A landscape silvicultural prescription must contain all of the components that clearly reveal how the agency intends to manage each forest patch within a landscape to achieve a desired sustainable condition. Thinning and regeneration harvest methods, for example, are appropriate tools for achieving some of these objectives, as is prescribed burning. Within patches that were ordinarily long lived, selection methods that perpetuate late-seral species and multi-cohort stands may be appropriate. Group selection methods may be appropriate in dry ponderosa pine series landscapes to mimic small patch regeneration that historically occurred as a result of regular underburning. Dwarf mistletoes should be managed according to historical fire disturbance regimes and their effects, which would eradicate mistletoes in some patches and minimize them in others, according to the historical variability of fires. Similarly, other insect and disease disturbances and effects would be managed to within historical ranges, according to the pattern of landscapes.

Current stand boundaries are an artifact of timber harvest entries and historical disturbance patterns. Silviculturists will often need to look past current stand boundaries to determine the future boundaries of patches. Patch size and edge determinations should be influenced primarily by historical disturbance probabilities and effects, environmental gradients, soils, hydrology, geomorphology, and potential vegetation.

Most vegetation management to achieve desired landscape mosaics will be through various silvicultural techniques. When harvest systems are used to achieve landscape goals, logging systems should be carefully prescribed to achieve long-term goals for soil and water productivity. The standard of accountability should be clearly presented to prospective purchasers of agency timber. Operators should be required to demonstrate that they have or will obtain the appropriate harvest technology, and that they have a track

record of operating within the bounds of silvicultural prescriptions. Only operators having a demonstrated track record of accountability should be allowed to successfully bid for landscape management projects on public lands. Harvesting can produce both beneficial and damaging effects to residual vegetation, soils, and water quality. The agency should be vigilant in administering vegetation management projects to achieve only the desired ends. The agency also should adequately finance project administration; inadequate funding is a problem of long standing that deserves resolution.

Question 5: What are alternative ecosystem management scenarios? What process should be used to evaluate alternative rates of investment in ecosystem management?

(References: All Volumes)

Introduction

The decision by the USDA Forest Service to manage for sustainable ecosystems requires that public land managers and resource management specialists understand and manage toward long-term ecosystem sustainability for generations of people who directly and indirectly benefit. To identify the desirable rate of investment in ecosystem management, decision-makers must at least understand the chief biological, physical, social, and economic consequences of each alternative. *To make informed decisions that favor sustainable ecosystems and a sustained flow of values, goods, and services to an evolving society with changing preferences, analyses should be undertaken to project the major consequences of alternative decisions.* In this role, science serves society by providing information that defines opportunities and limits in the decision process. Under ecosystem management, science continuously improves the knowledge base for decisions and clarifies which decisions likely will lead to sustainable ecosystems.

We propose a systems model[2] to evaluate biological, physical, and socioeconomic outcomes associated with alternative levels of investment (see appendix C). In ecosystem management, this model would include submodels of ecosystem components. For example, input variables would be the *yield functions* for such things as timber, wildlife habitat, fish habitat, rare plant and animal species, edible mushrooms, beargrass, yew, and huckleberries. The input variables would represent the array of goods, services, values, processes, and interactions derived from or defined by the conditions and potentials of each ecosystem. Output variables *(yields)* would include timber, beargrass, yew, huckleberry, and mushroom production, fish and wildlife habitats, stand conditions (seral stages), stand disturbance, jobs, and community stability (at least that part that is a function of natural resources management). Selected output variables would provide boundaries within which decisions could be made about the biological and socioeconomic acceptability of alternative investment levels.

The Process for Evaluating Investment in Ecosystem Management

As scientists assist in answering broad public policy questions, the challenge is to balance concerns about fitness and diversity of ecosystems with social and economic concerns, and with a philosophical view of how society values renewable natural resources. Different scientific disciplines take different approaches to this problem. An economist might rank ecosystem management alternatives by their marginal return on investment. A sociologist might rank them according to their capacity to mirror the values, philosophies, and aesthetic preferences of a major cross-section of society. Various biologists might rank them by their capacity to maximize biological diversity and ecosystem stability. Each method of ranking suggests a different "best" management, laden with the values of the particular point of view. The challenge of ecosystem management is to manage in ways that are both socially and biologically sensitive.

[2] The use of the term model here means the development of abstract representations. It takes on a semimathematical definition only when the discussion turns to model specification and solution.

To clearly distinguish differences in rates of investment, the major social and biological outcomes that characterize each alternative must be quantitatively projected. Such projections allow side by side comparison of the merits of alternatives and give a basis for decisions. In the same way that forest growth and yield models project periodic change in tree attributes and volume accrual for alternative silvicultural treatments, *projections are needed for alternative rates of investment in ecosystem management that report outcomes in the terms of the major social, biological, and economic decision variables. Subsequent analyses of uncertainty, hazard, and risk permit determination of the most and least robust of the alternatives.*

It is initially helpful to decompose the analysis process into its constitutive parts. The biological and physical portion of the analysis examines the biological and physical feasibility of alternatives, given current conditions of vegetation, environmental and edaphic conditions; changing climate and environment; the influence of historical conditions; the timing, kinds, and magnitudes of management inputs; and associated risks and uncertainties. The socioeconomic portion of the analysis examines the costs and benefits to society, congruence with social values and expectations, conservation of future management options, opportunities foregone, trade-offs, and resistance to management redirection in the future.

When alternative rates of investment are arrayed, they could be described in ecological, social, or economic terms, which would lead to three quite different analyses, each differing in utility for decision-making. If the alternatives were described in terms of economic sustainability, they might range from marginal to optimal economy. Only some of these alternatives would also be sustainable ecologically. The same is true if alternatives were described purely in terms of social sustainability. The charge given to the Eastside Science Panel was to speak directly to how the National Forest System can move toward more sustainable ecosystems. Consistent with that charge, we describe alternative rates of investment in ecosystem management in ecological terms. Social and economic projections would then be made for each alternative.

Alternative Rates of Investment in Ecosystem Management

What apparently has prompted the need for an assessment of the health of eastern Oregon and Washington ecosystems is widespread social concern over the declining long-term health and sustainability of eastside ecosystems. Changing societal attitudes toward public land stewardship now emphasize "healthy forests" and ecosystem (including human communities) sustainability, in addition to consumptive and extractive land uses. There is growing popular demand for land management that considers the condition of ecosystems available to future generations. The recent debate over habitat protection for the northern spotted owl and Columbia and Snake River sockeye salmon stocks illustrates the willingness of society to substantially reduce timber harvest levels and future economic expectations, in favor of ecosystem-oriented values.

Against this backdrop of changing societal values, we must select from an array of alternatives, one that best fits societal expectations and that will result in sustainable ecosystems. Differences among alternatives are expressed in ecological, social, and economic terms, and they are the points of comparison. In the process, we propose that (recalling the systems model we are using) various biological measures (input variables) frame decisions. From a broad range of possibilities, we propose five levels of investment in ecosystem management (also see table 1):

Level 1—Avoiding Catastrophe

The most severely dysfunctional and unstable landscapes and aquatic ecosystems are stabilized to avoid catastrophic resource damage, loss of species or populations, and loss of management or ecological options. High-hazard landscapes (fire, insects, diseases, erosion) and those that are severely fragmented or have severely degraded habitats, severely degraded air and water quality, soil productivity, or wildlife and fish habitats are stabilized against further degradation. Endangered species are protected with remedial management against irretrievable loss. High-hazard landscapes and aquatic ecosystems are monitored to ensure stabilization.

Level 2—Avoiding Catastrophe and Preventing High Hazards
Level 1 is attained, and no new high-hazard landscapes develop. Moderately hazardous landscapes (fire, insects, diseases, erosion, severely fragmented or degraded habitats) and moderately degraded air and water quality, soil productivity, and wildlife and fish habitats are also stabilized to prevent the development of additional high hazard landscapes. Threatened and endangered species, populations, and ecosystems are protected with remedial management against irretrievable loss. No new species are endangered. High- and moderate-hazard landscapes and aquatic ecosystems are monitored to ensure stabilization of high-hazard landscapes and that no new high-hazard landscapes develop.

Level 3—Restoring High-Hazard Landscapes and Aquatic Ecosystems
High-hazard and severely degraded landscapes and aquatic ecosystems are not just stabilized; structures and processes are restored to within historical ranges of variability. Endangered species and populations are restored to sustainable abundances and distributions to allow de-listing. Air and water quality, and soil productivity are restored to within historical ranges of variability. High- and moderate-hazard landscapes and aquatic ecosystems are monitored to ensure that high-hazard landscapes are restored and moderate-hazard landscapes stabilized.

Level 4—Restoring High- and Moderate-Hazard Landscapes and Aquatic Ecosystems
High- and moderate-hazard landscapes and aquatic ecosystems are not just stabilized; structures and processes are restored to within historical ranges of variability. Threatened and endangered species, populations, and ecosystems are restored to acceptable abundances and distributions to allow de-listing. High- and moderate-hazard landscapes and aquatic ecosystems are monitored to ensure their restoration.

Level 5—Eastwide Restoration of Ecosystem Sustainability
All landscapes and aquatic ecosystems are restored, to the extent possible, to the historical range of conditions with critical structures and processes restored to within historical ranges of variability. Threatened, endangered, and sensitive species are restored to sustainable abundances, and major indicator species and habitats are regularly monitored for their quality, distribution, and abundance to avoid management-induced loss of species. All landscapes and aquatic ecosystems are routinely monitored to detect changing conditions relative to historical ranges of variability.

Decisions on the appropriate sustainable (*sensu* Overbay) level of ecosystem management emphasis have biological, physical, and socioeconomic dimensions. Analyses rooted in the biological and physical sciences examine the capacity of ecosystems to achieve the proposed ends and the kinds, timing, and amounts of management needed and possible. This portion of the decision is about system capacities and technical feasibilities.

Analyses rooted in the social sciences examine society's interests in ecosystems and the benefits, costs, and trade-offs to society of alternative investment rates in ecosystem management and alternative ecosystem conditions. This portion of the decision is about congruence with social values and expectations; degrees of acceptability and economic feasibility are the measures.

Biological and Physical Feasibility Analyses

Whether an area under consideration is a single landscape, a river basin, or the whole of eastern Oregon and Washington, what is ecologically sustainable must be considered in terms of what has been sustained. Ecosystem capacities are influenced not only by their climate, soils, and geography, but also by their disturbance and developmental histories. To understand what is feasible to undertake in terrestrial (including riparian) and aquatic ecosystems, the events and circumstances that have produced the current conditions must be understood. Even more important, differences between any current managed condition and historical conditions must be understood.

Inhabitants of any ecosystem respond to the structures and processes available to them. If all requirements for survival and reproduction of an organism can be met within an ecosystem or some arrangement of ecosystems, that area is suitable habitat for the organism. Plant and animal species in terrestrial environments respond to specific vegetation conditions, patterns of vegetation within and among ecosystems, and the myriad associated processes. To understand the potential influences of various management actions on plant and animal species and their habitats, conditions within patches (more or less homogeneous units of pattern) and within landscape mosaics must be characterized to give some insight into the capacities of species, populations, communities, ecosystems, and landscapes that may be amenable to particular management actions.

Terrestrial landscapes considered for sustainable ecosystem management should be characterized according to their disturbance regimes, vegetation structure and composition, pattern of seral stages, distribution of patch sizes, age and size classes, densities, complexity of patch edges, and heterogeneity (diversity). Patterns in vegetation conditions will be apparent according to management history, geomorphology, soils, climate zones, disturbance regimes, hydrologic regions, and potential vegetation. Landscape hazards and risks must also be assessed, including fire, insect, disease, and erosion hazards, and a range of plant and wildlife viability analyses, habitat fragmentation analyses, and analyses of landscape and species diversity. Characterizing premanagement-era vegetation conditions is useful to indicate landscape patterns and hazard levels ordinarily a part of terrestrial ecosystems and landscapes. *Hazard and risk analyses provide useful information on the likelihood that management objectives will be met, thereby improving measures of uncertainty and robustness of management alternatives.*

In riverine ecosystems, geomorphic and hydrologic features of each river and stream must be characterized. These features include but are not limited to, stream hydrographs—especially storm flows and low flows; amount and location of sinuous reaches; channel habitat profiles (pool and riffle frequencies); dominant substrate sizes; profiles of large woody debris; active channel and floodplain characteristics; accumulated fine sediments; stream lengths on bedrock; side channel frequencies; and streambank and floodplain vegetation. Riverine ecosystem hazards should also be assessed, including various analyses of habitat condition and morphological condition, buffering capacity, and reach successional dynamics. Characterizing presettlement hydrologic conditions and associated hazards is again useful to indicate conditions and hazard levels that were ordinarily a part of riverine ecosystems.

To undertake an analysis of the biological and physical consequences of ecosystem management alternatives for the entire east side of Oregon and Washington, an area representative of eastside ecosystems would need to be sampled, model projections of alternative levels of ecosystem management run, and the outcomes compared and evaluated. Such an analysis would necessitate developing a large database, use of a geographical information system linked to stand growth and yield models (Stage 1973), or inventory projection systems (e.g., ATLAS, Mills and Kincaid 1992), insect and disease model extensions (Crookston and others 1978, Hawksworth and others 1992, Marsden and others, in press, Monserud and Crookston 1982, Sheehan and others 1989, Stage and others 1990), fire and air-quality models, and fish and wildlife habitat models. A parallel-processing model extension (Crookston and Stage 1991) of the base projection system could be used for analysis of landscape-scale consequences. *What is needed is a modeling framework that allows the simultaneous simulation of multiple insect and disease agent dynamics, fire conditions, and plant, wildlife, and fish habitat conditions, according to time-step projections of changes in vegetation structure and composition. Such a model does not exist.*

To manage the scale of this type of analysis, landscape modeling units could be derived from larger geographic areas like river basins or ecoregions (Omernik and Gallant 1986). Areas could be stratified by Landtype Association or an equivalent classification that groups individual landtypes by similarity in geomorphology, hydrology, topographic position, soils, and potential vegetation. Geographically and

functionally connected ecological landscape units could be further identified. These areas would be similar in potential vegetation, soils, landform characteristics, and processes like erosion, fire disturbance, insect and disease ecology, climate, and herbivory. They would be functional landscapes comprised of interacting ecosystems, and they would form the base analysis unit. Modeling subunits would be identified by examining the components of pattern of each landscape. Nearly all projected outcomes would be associated with some uncertainty because most of the modeled processes and outcomes are stochastic rather than deterministic. Analysis of occurrence probabilities would be completed for each important outcome and consequence of management to determine differences in robustness of alternatives.

Analysis of Social Acceptability and Economic Feasibility

Assessing social or economic feasibility is extremely difficult without being able to articulate both in the sense of what society gets from ecosystem management. Two central goals underlie any analysis of social acceptability and economic feasibility for ecosystem management:

- Establishing societal values and expectations, and willingness to pay for goods and services produced by managed ecosystems.

- Explicitly linking what is valued with what is measured.

From an economic standpoint, one surrogate method for dealing with this vagueness in the ability to describe what is being produced is to measure its value in terms of opportunity costs. Opportunity costs are the production costs of a particular product reflected as the value of the best foregone alternative. For example, if new standards for riparian zone management are adopted that reduce the amount of timber available for harvest in a particular watershed by 5 percent, the opportunity cost of that decision is the reduction in available harvest volume times the value of the timber (assuming timber is the highest alternative use). Land managers will need to make sure that costs are explicit so that they have a gauge for judging the magnitude of benefits.

Other economic considerations raised are the questions of who gains and who pays. If we are dealing with issues where the public gains, then we need to identify and assign the cost to the public. For example, State forest-practices acts often prescribe actions on private timberlands that benefit the public at large, with little direct compensation to private timberland owners for the costs incurred by them. In both Washington and Oregon, considerable resistance to expanding forest-practices regulations has arisen over the question of who should pay for management actions that primarily benefit society.

No magical way has been found for evaluating the full range of values for the bundle of goods and services expected from ecosystem management. This lack has at least two important implications:

- In spite of what society values, costs and benefits for most of the goods and services that can be derived from ecosystem management may be quantified either directly or indirectly in terms of timber values.

- Efforts to develop greater specificity for values will require more explicit notions of ecosystem outputs—both amounts and timing. Part of the issue is that it is essential to explicitly link what is valued to the measured outputs.

Several spatial scales should be considered to assess social acceptability and economic feasibility: local, regional, national, and global. It will be difficult to assess what society values at the local scale. Essential to understanding the current expectations of society is the process of establishing a dialogue with interested people, and other Federal, State, and private landowners. Some questions that must be addressed are:

- ❑ What do people expect from managed ecosystems on public lands?
- ❑ What are they willing to accept in trade-offs?
- ❑ To what extent are they willing to cooperate with management of public lands by adjusting management on nonpublic lands?
- ❑ What are they willing to forego to have sustainable ecosystems? How much are they willing to forego?
- ❑ What cost is too much? How much benefit is enough?
- ❑ What amount of benefits are they willing to invest in, in the long-term, given opportunities elsewhere?

Once input of this kind is obtained, the information can be used to select the ecosystem management alternative that is modeled. When analysis is complete the results can be communicated to interested stakeholders in terms of socioeconomic costs and benefits, and ecological gains and losses. Information shared in the dialogue would likely revise public expectations and subsequent analyses. Policy-makers can then make more informed decisions, knowing that alternative futures have been considered in terms of ecological and socioeconomic costs and benefits. Analysis of economic effects may be more relevant at the regional rather than at the local scale because of opportunities for substitution between local places within ecosystems.

At national and international scales, dialogue about and resolution of the global effects of management are essential among countries trading energy and forest products in the world marketplace. If governments operate independent of this dialogue, or if they let the market decide the fate of world forests, the possibility of global ecological sustainability is doubtful. The United States and every other country deriving products from its forests have responsibility in global sustainability, and each forested region must carry a portion of that responsibility. Nations must plan for global ecological sustainability or it will not be achieved. They must decide how much timber can be sustainably harvested, who will harvest it and when, who will develop technologies and produce alternatives to wood products, who will prefer sustainable ecosystems, and who will not. The United States, as the world's largest importer of softwood timber, should assess its effects on the Canadian forest sector, its largest trading partner. In a global sense, the United States should assess the need for, and the state of, ecosystem management as part of global environmental policies that may be driven more by energy concerns than ecological or forestry concerns.

Comparison of Alternative Rates of Investment

The basic process of comparing alternative rates of investment in ecosystem management is built around a systems-modeling view (see model in appendix C) of ecological and social processes at stand, landscape, and regional scales. This model can be used to simulate the development of forested landscapes over time under alternative futures and management strategies. The approach differs from traditional modeling (and particularly forecasting) approaches by directly treating uncertainty in the analysis. In the modeling literature, this approach has been called scenario planning (Wack 1985). Scenario planning, as it is usually applied, does not attempt to predict the future; instead, it postulates a set of plausible futures depending on the assumptions underlying that future. Thus, the technique focuses on what might happen or go wrong and how to deal with it, as opposed to planning from a predetermined future.

Scenario planning has been around, both in the general and forestry literature, since the mid-1980s.[3] Some of the earlier applications dealt with the turbulent oil markets of the 1970s (Wack 1985). In forestry, scenario planning techniques have been a part of the RPA efforts since 1983 (Haynes 1990, U.S. Department of Agriculture 1983). Most forestry applications take a classical sensitivity analysis approach: a limited number of key input and output elements of the model are varied, and results of the key projection are examined for differences. These differences allow identification of emerging problems and measurement of the effectiveness of possible solutions to various problems.

The Next Step

The Eastside Science Panel was asked to evaluate the effects of nine decades of timber and resource management on terrestrial, riparian, and riverine ecosystems of eastside Oregon and Washington. They have reported on changes in ecosystems from historical to current conditions under the influence of management. *They suggested that management practices of the future should direct current ecosystem structures and processes toward historical ranges of variability, not because these are the only trajectories that can be followed successfully, but because they are perhaps the most robust or most probable, given knowledge and successes to date.*

The National Forest System and Forest Service Research should present research in frameworks that allow interested people to assimilate and use the information. This proposition is not simple because it calls for improving the quality of our science, our ability to integrate different types of science, and our ability to clearly communicate information to diverse audiences. These frameworks need to be free of embedded values and value judgements (e.g., forest health is good or bad), and we need to be able to extrapolate our research to broader spatial scales. Given that policy debates and controversy are an inherent aspect of the formation of public values and understanding, scientists have the opportunity to improve clarity of reasoning and decisions when information for decisions is inadequate. Finally, we need to carry our science to the issues—the need for care and thoughtfulness, not simple crisis reactivity is real. If we continue to be reactive, the danger is that we will contribute to the ideological stand-off by offering value-laden, all-or-nothing choices.

What remains to be done—and was not a part of the charge of the Eastside Science Panel—is to clearly assess the rate of investment in ecosystem management that is congruent with social expectations, values, and economic interests. The quantitative simulation of alternative investment strategies we have suggested is necessary to frame decisions that will be made, and provide an understanding of the differences in costs and benefits to society. We expect that society will want to run analyses of this sort regularly to recalibrate its expectations of what should be done when financial resources are limited, and when preferences and values have changed. The Forest Service has adopted a new policy of sustainable ecosystem management whereby society and ecosystems both benefit in the long term. Lacking the sort of analysis we have proposed, decisions to proceed with some level of ecosystem management emphasis would be based on information primarily from the biological and physical sciences, or social sciences, failing to confront the first premises of ecosystem management.

[3] Before the mid-1980s, these same techniques were described in the simulation literature as a policy simulations approach (Naylor 1970). The simulation approach was seen as having an advantage over the more commonly applied optimization approaches in that it did not require knowledge about the policy maker's welfare preferences or particular targets, but still provided the policy-maker with information necessary for decisions.

Table 1. Alternative Levels of Investment in Ecosystem Management.				
Investment Levels	Diversity: Threatened Endangered Sensitive Species	Productivity: Air Quality Water Quality Soil Productivity	Structures and Processes Stabilized Rehabilitated	Level of Monitoring: Protection Prevention
Level - 1 Catastrophe Avoidance	Endangered species protected against irretrievable loss only	Air and water quality, and soil productivity stabilized against further degradation on high-hazard landscapes only	High-hazard and severely degraded landscapes only are stabilized avoiding catastrophes	High-hazard and severely degraded terrestrial and aquatic ecosystems are monitored
Level - 2 Catastrophe Avoidance With High-Hazard Prevention	Endangered species protected against irretrievable loss; Threatened species protected to avoid endangerment	Air and water quality, and soil productivity stabilized against further degradation on high- and moderate-hazard landscapes	High- and moderate-hazard landscapes are stabilized, new high-hazard conditions are prevented	High- and moderate-hazard terrestrial and aquatic ecosystems are monitored
Level - 3 Restoration of High-Hazard Landscapes and Aquatic Ecosystems	Endangered species and populations are restored allowing delisting	On high-hazard landscapes, air and water quality, and soil productivity are restored to within the historical ranges of variability	On high-hazard landscapes, structures and processes are restored to within the historical ranges of variability	High- and moderate-hazard terrestrial and aquatic ecosystems are monitored
Level - 4 Restoration of Moderate- and High-Hazard Landscapes and Aquatic Ecosystems	Threatened and endangered species and populations are restored allowing delisting	On high- and moderate-hazard landscapes, air and water quality, and soil productivity are restored to within the historical ranges of variability	On high- and moderate-hazard landscapes, structures and processes are restored to within the historical ranges of variability	High- and moderate-hazard terrestrial and aquatic ecosystems are monitored
Level - 5 Eastside Restoration of Ecosystem Sustainability	Threatened, endangered and sensitive species and populations are restored allowing delisting	Air and water quality, and soil productivity are restored to within the historical ranges of variability on all landscapes	Structures and processes are restored to within the historical ranges of variability on all landscapes	All terrestrial and aquatic ecosystems are monitored regularly to detect any management induced degradations

Question 6: What monitoring strategy is appropriate for maintaining sustainable ecosystems?

(References: Volumes II, III)

Monitoring for Sustainability

Monitoring of ecosystem management must evaluate agency effectiveness in conserving biological diversity and long-term site productivity, and the capacity of ecosystems to provide sustainable flows of renewable resources. An enduring commitment to funding and personnel is required by the National Forest System and Forest Service Research if monitoring of ecosystem management experiments is to be satisfactorily achieved. Accurate baseline data are needed to monitor ecological trends and the status of landscapes. The knowledge base must include an inventory and classification of historical and current conditions; lacking these data, monitoring inputs to ecosystem management will be qualitative and of limited use. An effective monitoring program must:

- Ensure accountability of management actions to societal expectations, management plans, and decisions.
- Evaluate ecosystem management experiments and provide both positive and negative feedbacks for determining future management actions. In this capacity, monitoring folds the results of prior management experiments back into ongoing analysis and decision processes, thereby improving understanding of ecosystem structures, processes, and responses to management, and improving the quality and certainty of decisions.
- Periodically measure attributes of landscapes and ecosystems that are indicative of trends in landscape and ecosystem structures, processes, and flows.
- Continually assess and evaluate plant and animal species viabilities, soil productivity, and water and air quality. Air quality monitoring should include monitoring for potential increases in smoke emissions associated with fire hazards. Water quality monitoring should address water purity and aquatic habitat considerations.

Sustainable ecosystems are defined in both ecological and social contexts. A monitoring system should integrate social and ecosystem values to assess the congruence of management actions with societal expectations, and test the ecological sustainability of those expectations. Changes in societal perceptions, values, and expectations of public forest lands, and agency response to that evolution should be monitored locally, regionally, and nationally.

Current Monitoring Efforts

National Forests in the Pacific Northwest Region are currently responsible for monitoring condition and trends of water quality, riparian ecosystems, long-term soil productivity, and air quality (U.S. Department of Agriculture 1992c). Insect activity, fuels treatment activities, and vegetation management practices are also monitored under separate strategies, and at differing scales and intensities. The Endangered Species Act requires monitoring of sensitive species and habitats. Forest plans currently require monitoring of management projects to ensure that they are initiated, completed, and meet intended results (National Environmental Policy Act [NEPA] of 1976). The amount of monitoring done in the Region is rapidly increasing, evidenced by special monitoring strategies for the northern spotted owl (Thomas and others 1990) and for sensitive salmon stocks (U.S. Department of Agriculture 1992d), but current monitoring is piecemeal rather than part of a coherent monitoring strategy for all species, processes, and ecosystems.

Formal and informal means of monitoring societal needs and expectations of resources and landscapes currently include public involvement and scoping processes in forest- and project-level planning. Conflict resolution exercises have also provided some insight into societal expectations, but on balance public land management emphasis has not been congruent with either societal expectations or values as evidenced by the endless appeals of forest plans, timber sales, and the imposing amount of litigation surrounding virtually all significant management actions.

Integrating Social, Economic, and Ecological Factors

A primary assumption of this monitoring approach is that most socioeconomic and ecological values and expectations of managed forests can be expressed in terrestrial and aquatic landscape patterns and processes. Levels of ecological and socioeconomic sustainability differ among landscapes. Resources generally occur in patches, clusters, or locally large aggregations on landscapes (Milne 1992). Forest stands ("patches") and stream reaches support variable quantities of resources (trees, owls, fish) having ecological as well as socioeconomic importance. Diversity of species, processes, habitats, ecosystems, and site potential should all be viewed in the same way that economic capital is viewed (Brooks and Grant 1992). *Alternative landscape configurations with their resultant processes and flows can be a direct expression of social and economic expectations. Monitoring should evaluate whether landscape management objectives are achieved, whether societal expectations are met, and whether societal expectations are compatible or in conflict with long-term sustainability of ecosystems.*

Monitoring Landscapes: Coarse-filter Approach

The "coarse-filter" ecosystem management approach (Hunter 1991) proposes that maintaining ecosystem and landscape structure and composition also conserves known and unknown species and processes within those landscapes. This concept is appropriate to landscapes that have nondisrupted disturbance histories and vegetation conditions that are consistent with historical ranges of variability. Current ecosystems have highly altered disturbance regimes, and resulting vegetation conditions are unstable and anomalous. Management practices of this century have unwittingly reconfigured and minimized a wide range of plant and animal habitats, and the viability of numerous species is in question. Because some species are threatened or endangered already, fine-filter conservation strategies are also needed in the lengthy transition period to sustainable ecosystems. Monitoring of threatened, endangered, and sensitive species is therefore also required (Thomas and others 1993). Noss (1990) suggested intensive monitoring should be conducted where ecosystems, processes, or species are at high risk; less intensive monitoring was suggested for non-critical landscapes. Noss recommended a coarse-filter management approach in general, with hazard monitoring for high risk fine-filter elements.

Proposed Monitoring Strategy

We recommend a three-part strategy for monitoring landscape attributes, sensitive species and unique habitats, and disturbance regimes and effects:

Element 1. Monitoring landscape structure and composition.

Element 2. Monitoring threatened, endangered, and sensitive species and unique habitats.

Element 3. Monitoring disturbance regimes, disturbance effects, and hazards.

Benefits in monitoring efficiency are derived when common attributes serve two or more elements simultaneously. This proposed system complements but does not duplicate monitoring programs described for terrestrial and aquatic ecosystems in the Environmental Monitoring and Assessment Program (Hunsaker and Carpenter 1990, Knapp and others 1991, Palmer and others 1992). To avoid a monitoring quagmire, further efficiencies should be explored, and scientific and public consensus achieved on appropriate strategies. A critical "short list" of monitoring variables should ultimately be identified to accomplish representative and cost-effective monitoring.

Element 1: Monitoring Landscape Attributes

- ❑ Classify, inventory, and characterize ecological landscape units and stream classification units for the whole of the eastside; establish and maintain a GIS database of conditions in each spatially referenced aquatic and terrestrial unit. Monitor trends over time in the attributes used to characterize landscape and stream units.

- ❑ Characterize, to the extent possible, historical structure, composition, and disturbance regimes of each landscape and stream unit as reference points.

- ❑ Identify and characterize sites within landscape and stream units that are particularly sensitive to management and disturbance effects. Develop monitoring criteria for these sensitive sites and monitor them regularly for early warning of ecosystem degradation.

- ❑ Develop reference sites from among the classified landscape and stream units to provide baseline understanding of ecosystem potentials. These sites are allowed to function as they normally would without management intervention. Fire, insect, disease, erosion, hydrologic, and other disturbances are allowed to run their course to the extent possible. Ecosystem structure, composition, and processes are monitored to provide reference points and ranges for variables of managed landscape and stream units.

The Ecological Landscape Unit

Under a coarse-filter management approach, analyses and decisions must consider and address multiple scales. Ideally, these scales would be represented by nested, ecologically meaningful units. The ecological landscape unit is recommended as the basic unit of management and monitoring, because these landscape areas of similar potential vegetation, soils, landform, and disturbance patterns are recognizable and replicable. These units respond similarly to natural processes of fire, insects, and pathogens, and management actions, although with differing spatial and temporal variations. Ecological landscape units are defined by their potential vegetation, soils, geology, hydrology, and disturbance regimes, and they can be supported by standardized data sets and analysis procedures.

In eastern Oregon and Washington where ecological landscape units have not yet been defined, an interim alternative would be to use watersheds or hydrologic units. Watersheds have been used previously as landscape units for studying landscape issues (Hornbeck and Swank 1992, Lotspeich 1980). Ideally, both ecological landscape units and watershed units should be considered in environmental effects analyses.

Sensitive Ecosystems: An Early-Warning System

Complete reliance on a coarse-filter management approach to monitoring may be inadequate because certain ecosystems are more susceptible to change than others. Accordingly, an early-warning system is needed for monitoring sensitive ecosystems and habitats. To be efficient, a filtering procedure should be used to identify ecosystems and habitats having a high probability of rapid response to management or natural disturbances. For example, riparian ecosystems are somewhat fragile and vulnerable to alteration in size, structure, and composition. Stream classification work in eastern Oregon and Washington (Kovalchik and Chitwood 1990), and research on stream-reach sensitivity to disturbance (Wissmar 1992) provide a framework for selecting sensitive riparian areas for monitoring.

Sensitive Ecosystem Components

Just as some sites are more sensitive to disturbance than others, some ecosystem components are more sensitive to disturbance or change than others. Useful monitoring indicators of sensitive ecosystem components should provide rapid and readily observable indications of change in response to disturbances or management alterations, have low variance in measurable parameters, be amenable to replication in

measurement, and be inexpensive to sample (Hunsaker and Carpenter 1990, Palmer and others 1992). For example, Marcot and others suggest in this report that eastside stream systems should be managed for native coldwater fish species that have very narrow physiological tolerances, and that require the highest water quality. Sensitive water quality monitoring characteristics for specific management practices are provided by MacDonald and others (1991).

Reference Sites

Multiple reference sites are needed in both terrestrial and aquatic habitats to characterize ecosystem potentials, processes, unmanaged ecosystem characteristics, and variability. Although societal goals may never be to achieve reference-site conditions, these sites would be useful for describing what is possible and sustainable in ecosystems they represent. Paired comparisons using reference sites would indicate changes in managed sites over time relative to unmanaged reference sites.

Element 2: Monitoring Threatened, Endangered, and Sensitive Species and Unique Habitats

Monitoring is currently required for each threatened, endangered, and sensitive species and their habitats under the Endangered Species Act. This requires significant effort (Thomas and others 1990, 1993) and results in a highly fragmented approach that has been characterized as "crisis management" for an ever-expanding number of endangered species (Szaro and Salwasser 1991). Marcot and others discuss, in this report, the need for both individual species and coarse-filter approaches to monitoring for biodiversity. They preferred the "all species" monitoring scheme proposed by Thomas and others (1993) that calls for consideration of the broadest possible array of plant and animal species in a habitat-planning program. Absent is the recognition of some human habitat and resource needs and recognition of the dynamic nature of ecosystems and ecosystem processes. The "all species" approach recognizes the need to conserve species, but does not acknowledge the processes whereby they are conserved. A better balance of coarse- and fine-filter management and monitoring is surely needed.

It would be somewhat naive to assume that there will be no additional irretrievable effects on species, habitats, or processes associated with past management practices. It would also be naive not to anticipate the future effects of increasing demand for forest resources as the human population expands. Accordingly, one objective of ecosystem management should be to make the most informed decisions possible about the consequences of management. Monitoring of threatened, endangered, and sensitive species and habitats should provide important data on the viability of various species, and it should also give insight to the likelihood of timely species recovery. Restoration and rehabilitation activities with a low probability of success should often be avoided. Scientists should assist in the decision process by providing information that will allow decision-makers to minimize adverse effects to species and productivity and maximize management options and resources for people of current and future generations.

Element 3: Monitoring Disturbance Regimes, Disturbance Effects, and Hazards

Disturbances large and small are responsible for the way current landscapes appear and function today. Disturbances of various kinds and intensities will determine the structure, composition, and function of future landscapes. Historical landscapes and ecosystems carry important clues as to their disturbance history, and the effects of those disturbances on diversity and productivity. Toward disturbing landscapes (via various management practices) in ways that conserve diversity and productivity, it is insightful to learn about the disturbance regimes that sculpted landscapes of the past. It is equally insightful to discover the range of effects associated with those historical disturbance regimes. Accordingly, historical disturbance regimes and effects should be studied and documented as representative of all managed landscape and stream units and contrasted, by means of disturbance monitoring, with current disturbance regimes and effects.

A hazard in ecosystem management is the risk or a danger of an unwanted outcome. Hazard analysis measures the susceptibility of landscape and stream conditions to unwanted effects. Hazard monitoring measures changes in hazard status at regular intervals, thereby providing important insights to the probability of future unwanted occurrences. *Hazard monitoring gives decision-makers a clearer idea of the management actions that have the highest probability of achieving management goals, and it often speaks to the appropriateness of certain management goals.* Recent assessments for eastern Washington showed elevated insect, disease, and fire hazards. Hazard analyses of this eastside assessment revealed increasing insect, disease, and fire hazards in many watersheds. Hazard monitoring is one clear way to minimize some of the uncertainty associated with ecosystem management decisions.

Nationally, a three-tiered forest health monitoring system has been established in the contiguous United States to document changes in forest health conditions over time (Shaw 1991). The monitoring system will annually sample some 400 "sentinel plots" nationwide that were designed to closely conform with the forest monitoring network of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) (Hunsaker and Carpenter 1990). The system will provide information useful to regional and national forest health assessment, but it is not suited for hazard assessment at smaller scales.

Adapting Monitoring to Spatial and Temporal Scales

The time required to detect change depends on the scale and intensity of disturbance. Changes in landscape structure or function are temporal- and spatial-scale dependent; consequently, a landscape may be considered stable at one scale and disturbed at another, smaller scale. Monitoring of disturbance events therefore usually occurs simultaneously at three different spatial scales. An event at one scale is analyzed for significance in the next greater hierarchical scale, and the mechanism of the event is explained in the next lower scale (Urban and others 1987).

Question 7: What are the information gaps and research needs in prescribing and managing for sustainable ecosystems?

(References: All Volumes)

The Secretary of Agriculture directed the Forest Service, and specifically the science panel, to address five questions dealing with sustainable ecosystems in eastern Oregon and Washington, and to identify information gaps when those questions could not be answered satisfactorily. The following discussion presents the information gaps that limit our ability to provide a complete answer to each question addressed in the executive summary. Questions are provided first, and information gaps pertaining to each question are then discussed.

> *Question 1: What process should be used to generate and evaluate alternative sustainable ecosystem management scenarios?*

Ecosystem management is displayed as the optimum integration of societal values and expectations, ecological potentials, and economic considerations. Although rapid progress has been made in landscape ecology and conservation biology much development and testing is required to provide a solid basis for management (Gordon Oriens, personal communication with R. Everett).

- An effective process is needed for assessing societal expectations for eastside landscapes. That process must then develop those expectations through dialogue and analysis into landscape designs that are socially desirable, technologically feasible, and ecologically sustainable.

- Analysis is needed to determine the rate of investment society is willing to make in ecosystem management. That analysis will determine whether ecosystem management is a process for minimizing catastrophic losses and hazards to resources and ecosystems or a means to restore ecosystems and landscapes to sustainable conditions for current and future generations.

- Detailed knowledge of the successional dynamics of eastside forest and range ecosystems is needed to translate historical patterns of seral and structural stages resulting from various disturbances into designs for future sustainable landscapes. This information will substantively improve the robustness of future landscape designs and it will allow clear articulation of sustainable desired future conditions.

- Methods are needed to describe and measure new landscape designs in terms of the locations, characteristics, and abundances of renewable resources, and ecological and social values.

- Procedures are needed that will facilitate consideration and comparison of mixes of traditional market (timber, livestock) and nonmarket values (recreation, aesthetics, water quality) by decision-makers as they consider alternative investment futures, and alternative landscape designs.

- Economic and sociological research is needed to reveal how the perception of risk to resources and ecosystem sustainability from fires, insects, diseases, and the like affects societal values and preferences.

- Economic incentives for adjacent landholders should be explored for those who wish to participate in or cooperate with ecosystem management on public lands.

Question 2: Is the Available Scientific Information Adequate to Prescribe for Sustainable Ecosystems?

There are numerous alternative states for ecosystems; some conserve site productivity and biological diversity, while others clearly forfeit future options. A conservative approach would maintain ecosystem structures and processes within historical ranges of variability by mimicking the effects of disturbances that maintained this range of vegetation patterns. Historical landscape patterns may not meet society's current or future expectations, and other states may be prescribed that better meet expectations, but there is no information available as to their potential sustainability. Given current ignorance and poor success with landscape designs alternative to historical conditions, it is prudent to validate the sustainability of other states first before they are widely prescribed.

Land managers are currently limited in their prescriptions for sustainable ecosystems because they lack an adequate inventory and characterization of current landscape conditions, societal expectations are as yet poorly understood, and sustainable target landscape conditions have not been articulated for each landscape. The following needs are apparent:

- ❑ A comprehensive inventory and classification of terrestrial and aquatic ecosystems are needed. Ecological landscape units and stream classification units should be identified and characterized; these units are the building blocks of an hierarchical approach to ecosystem management.

- ❑ The historical ranges of conditions of landscape and stream units and their historical disturbance regimes should be quantified.

- ❑ Significant differences in tactics and outcomes are associated with implementation of coarse- and fine-filter conservation strategies. Because some plant and animal species are already threatened or endangered, the agency is legally responsible for developing and implementing fine-filter conservation strategies to restore viability of each of these species. *While all species contribute to ecological sustainability, a fine-filter conservation strategy for one or several species may be in conflict with sustainability of other species, structures, or processes of ecosystems. This conflict of purposes may lead to failure of one or both strategies in specific instances. Remedies to conflicts should be sought now, and solutions identified that minimize adverse effects on all aspects of ecosystem sustainability.*

- ❑ Early-warning monitoring systems are needed to alert land managers to potential hazards to diversity, productivity, or resource sustainability.

- ❑ Monitoring standards and techniques are needed to evaluate landscape management projects. Monitoring should ensure that landscape management projects were implemented as designed, that they were acceptably effective, and that landscape management experimental hypotheses are validated or invalidated.

Question 3: Are eastside ecosystems in Oregon and Washington stressed and in need of restoration?

Several disturbance types (fire, insect, disease, grazing, and hydrology) were identified as significantly outside historical ranges of variability; these irregularities in disturbance frequency, intensity, and duration contribute to the development of stressed and unstable ecosystems on the eastside (Volume III). *The application of management practices that restore disturbance effects to levels consistent with sustainable landscape designs is the first step in creating sustainable eastside forest ecosystems.* A list of other related research and information needs follows.

- ❑ Research is needed on the extent to which management practices can and should be used to mimic the scale, distribution, intensity, duration, and frequency of historical disturbances. Research should also determine the essential disturbance effects which have no acceptable substitutes.

- ❑ Salvage logging has often been associated with safeguarding landscapes against catastrophic fires. Appropriate use of salvage operations should be investigated to ensure that economic and ecological considerations are adequately addressed.

- ❑ Management actions are needed that safeguard landscapes against catastrophic losses in biodiversity and long-term site productivity from insect outbreaks, disease epidemics, overgrazing, erosion, roading, or catastrophic fires. Management actions should be long-term solutions, but short-term measures may be applied if they are cost effective, and provide needed planning and analysis time to develop robust, long-term landscape management alternatives.

- ❑ A budget process is needed at national and regional levels that explicitly funds ecosystem management objectives. Since ecosystem management is now the central focus of the agency, budgeting should reflect that emphasis. Vegetation management goals can be budgeted in an operations budget, one part of which is timber production.

- ❑ Data concerning historical disturbance effects should be collected on representative stream and landscape units.

- ❑ Development of the ecosystem management approach should continue.

Question 4: What are the effects of management practices on ecosystem sustainability? What changes are needed in current management practices? What are the knowledge gaps that prevent adequate evaluation of current management practices?

Most forest management practices were originally developed for resource extraction, not for conservation of biodiversity or long-term site productivity. The major changes needed in current management practices are changes in the objectives to which they are applied. New standards and guidelines are needed to ensure that ecosystem management objectives are met, and some management practices should be adapted to fit landscape- and regional-scale objectives.

- Standards and guidelines should be developed for management of landscapes at multiple scales. These standards and guidelines should consider the historical range of conditions of landscape struucture and composition and historical ranges of variability of disturbance effects.

- Desired future condition statements should be developed for ecological landscape units. Such descriptions should prescribe for patterns and processes within historical variability ranges if alternative sustainable states have not been validated.

- Fire management goals will initially address hazardous fuel conditions on the most hazardous landscapes. Eventually prescriptions will be needed that incorporate managed and natural roles of fire.

- More data are needed on the combined long-term effects of livestock and wildlife grazing on soil, water, and plant resources. Integrated resource planning is needed on most rangelands.

- As many as 19,000 miles of roads may no longer be needed in eastern Oregon and Washington. Strategies are needed that will enhance wildlife habitat configurations while providing acceptable road access to public lands.

- The cumulative effects of management practices on landscape patterns and processes should be better understood. Research is needed to relate desirable cumulative effects to management practices.

Question 5: What are alternative ecosystem management scenarios? What process should be used to evaluate alternative levels of investment in ecosystem management?

Five alternative levels of investment in ecosystem management are provided for consideration by policy-makers. Selection of an appropriate investment level requires analysis of the major biological, physical, social and economic consequences of each alternative, and analysis of uncertainties to determine which alternatives are ecologically and socially most robust. To select the appropriate rate of investment in ecosystem management, policy-makers will need to:

- Assess social values and expectations for public forest lands.

- Articulate and quantify ecosystem management outputs in terms of societal values and expectations.

- Assess social and economic costs, benefits, risks, efforts, and trade-offs associated with alternative rates of investment in ecosystem management.

- Evaluate and compare long-term ecological and economic costs and benefits of prevention and rehabilitation approaches.

- Quantify current and future links between sustainable flows of renewable resources and management to mimic disturbance effects.

- Develop a landscape modeling framework that allows the simultaneous simulation of multiple insect and disease agent dynamics, fire conditions, and plant, wildlife, and fish habitat conditions, according to time-step projections of changes in vegetation structure and composition.

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APPENDIX A

The Eastside Ecosystem Health Assessment Science Panel

An interagency scientific panel met in Portland, Oregon, in September 1992 to create a framework for addressing concerns in the Hatfield/Foley letter. This panel was headed by Dr. Richard Everett and three science team leaders Drs. Mark Jensen, Paul Hessburg and Bernard Bormann. Scientific panel members involved in this process were:

Universities:
Dr. Jim Agee, University of Washington
Dr. David Baumgartner, Washington State University
Dr. John Buckhouse, Oregon State University
Dr. David Ford, University of Washington
Dr. William Krueger, Oregon State University
Dr. Chad Oliver, University of Washington
Dr. Mary Lynn Roush, Oregon State University

State Agencies:
Mr. John Mankouski, Washington Department of Wildlife
Dr. Ken Russell, Washington Department of Natural Resources
Mr. John Shumway, Washington Department of Natural Resources

Indian Nations:
Mr. Eric Hansen, Yakima Indian Nation

Private Sector:
Dr. Patrick Bourgeron, The Nature Conservancy
Mr. Rick Brown, The National Wildlife Federation
Dr. Larry Irwin, National Council for Air and Stream Improvement
Dr. Russel Mitchell, consultant

Federal Agencies:
Mr. Wayne Elmore, Bureau of Land Management
Dr. Hiram Li, U.S. Fish and Wildlife Service
Mr. Chuck Wendt, Bureau of Indian Affairs

Forest Service Research:
Ms. Martha Brookes
Dr. David Brooks
Dr. John Lehmkuhl
Dr. Patrick Cochran
Dr. Ross Kiester
Dr. Joe McNeel
Dr. Joseph Means
Mr. Jim Weigand
Dr. Boyd Wickman

Blue Mountains Institute:
Dr. Thomas Quigley

The Science Teams

Three science teams were created from members of the science panel and other scientists. An Implementation Framework for Ecosystem Management Team, under the direction of Dr. Jensen, was assigned the task of developing a framework for ecosystem management that could be applied immediately to eastern Oregon and Washington and other National Forest System lands. The Assessment Team, lead by Dr. Hessburg, was assigned the task of evaluating the effects of historical management practices on sustainability of eastside forest ecosystems using the framework provided by Dr. Jensen's team. The Framework Team, under the direction of Dr. Bormann, was assigned the task of developing recommendations for a new ecosystem management framework that would assist future management and analysis efforts. The results of these teams' efforts are found in their respective volumes of this report.

APPENDIX B

Review Process and National Forest Systems Assistance

Scientific Review

All documents written for this report have undergone a double-blind peer review. In this process the reviewers did not know the identities of the authors nor did the authors know the reviewers' identities. This process was graciously accommodated by Dr. Bruce Dancik, Department of Forest Science, University of Alberta, Edmonton, Canada. Review comments are on file at the Pacific Northwest Research Station, Portland, OR.

User Group Review Process

The process used and the topics to be addressed in this report were reviewed by concerned citizens in eastern Washington and Oregon. Citizens who participated in this review process included Mr. Duane Vaagen, Vaagen Bros. Lumber Co, Colville, WA; Dr. John Osborn, Inland Empire Public Lands Council, Spokane, WA; Ms. Shirley Muse and Ms. Judy Johnson, Audubon Society, Walla Walla, WA; Mr. Robert Klicker, private forest owner, Walla Walla, WA; and Mr. Robert Messenger, Boise Cascade Co., La Grande, OR. Their concerns and suggestions were used in the process and documents.

Senior Scientist Review

Several senior scientists were asked to review the process and the proposed contents of the report for compliance with the intent of the Foley/Hatfield letter. Dr. Jack Ward Thomas, Pacific Northwest Research Station; Dr. Wendall Hann, Northern Region; Dr. John Gordon, Yale University; Dr. Richard Haynes, Pacific Northwest Research Station; Dr. Jerry Franklin, University of Washington; and Dr. Pete Avers, NFS, WO, were the senior reviewers. Their comments and concerns were considered in preparation of this document.

National Forest System Cooperation in the Assessment Process

This assignment was conducted independent of National Forest Systems administrative supervision but could not have been accomplished without their full support. The Pacific Northwest Region and Northern Region provided scientific expertise on request and case histories where ecosystem management was already being implemented. The Pacific Northwest Region provided more than 100 people for current and historical photo-interpretation of approximately 1.1 million acres in eastern Oregon and Washington. The Northern Region provided personnel to develop computer programs for standardized ecological data sets and their analysis. The National Forest System is commended for their rapid response to requests for assistance. A liaison network was established within the National Forest System to provide information regarding this assessment to the Region (coordinated by Mr. Tim Rogan-Pacific Northwest Region); Forest Supervisors (coordinated by Mr. Sonny O'Neal, Wenatchee National Forest); and District Rangers (coordinated by Ms. Mary Erickson, Chemult Ranger District, OR). Scientists from the Intermountain, Rocky Mountain and Southern Forest Experiment Stations provided statistical advice or manuscripts for this report.

APPENDIX C

A Systems Model for Evaluating Alternative Levels of Investment in Ecosystem Management:

$$Y_t = C_1 Y_{t-1} + C_2 \begin{bmatrix} X_t \\ Z_t \end{bmatrix} + V_t,$$

where:

Y_t is a vector of variables determined in the solution process for time (t);

Y_{t-1} is a vector of lagged variables, which in this period (t) are treated as predetermined variables;

X_t is a vector of predetermined variables not influenced by events within the systems being modeled;

Z_t is a vector of postulated policy variables, whose values could change depending on what might happen within the systems being modeled or where policy interests intervene to change them;

V_t is a vector of stochastic disturbance terms; and

vectors C_1 and C_2 are model coefficients.

Model solution involves solving for Y_t in terms of Y_{t-1}, X_t, Z_t, and V_t. Given X_t and Z_t, we can explore evolutionary behavior in which the model generates its own values for the endogenous variable Y over many future periods. By manipulating the values of the postulated (policy) variables Z_t, the time paths of the solution variables are determined for each alternative level of ecosystem management. One caution is that the solution variables are the consequence of the assumptions. Changes in assumptions will change our view of future ecosystem states.

APPENDIX D

Authors of the Executive Summary

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